DISCOVERING WEATHER

JOHN S. BIGGS

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Foreword

This is a book for the weather enthusiast. It tells him everything he needs to know about the atmosphere, the effect of the sun, in fact all the elements that go to make what we call weather. It describes the things the weatherman has to know before he can draw up his weather forecasts. It explains the meaning of his 'depressions' and 'anti-cyclones' and 'cold fronts'.

There are exact descriptions of natural phenomena which are familiar to most of us – things like thunder and lightning, frost and fog – so that we can learn just what they are and how they are caused. Cloud formations, too, are listed and described, so that we can recognise them when we see them; and hurricanes and tornadoes are considered in detail.

This book gives a clear account of the meteorological service – how it came into being and how it collects the information which enables its members to give the weather forecasts. It tells what it is like to work on a weather station, and gives a full description of the instruments used and how they work.

There are ideas on how to set up a school weather station, and instructions for making some of the instruments that will be needed as well as practical suggestions for weather study and observation. And for anyone in doubt there is a glossary of weather terms and an index.

ALYS L. GREGORY

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1 Action in the Atmosphere

1. OUR ATMOSPHERE

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Unless a rocket travels upward at more than 25,000 miles per hour, it will not escape into space. If its speed is less than this, the force of gravity, that is the attraction of the earth, will be too great and will pull it back to the earth's surface.

The atmosphere, which is a thin film of air surrounding the earth, is similarly prevented from escaping.

The force of attraction of a body depends upon its size. Jupiter is three hundred times as big as the earth and its atmosphere is therefore very dense. The moon, on the other hand, is only one eightieth of the earth's size and it has practically no atmosphere at all. On neither could there be any form of life as we know it.

The temperature on the surface of a planet depends on its distance from the sun. Venus is much nearer the sun than the earth is, and it is thought that the excessive heat causes it to be shrouded in clouds of dust. Planets, like Neptune, which are many millions of miles farther from the sun, are believed to be covered with layers of frozen water, methane and ammonia. Indeed, the more we learn about the solar planets and the more commonplace excursions into space become, the greater is our appreciation of conditions on the earth. A brief glance at some of the facts will help you to realise why the atmosphere is often referred to as man's greatest resource.

The atmosphere at heights of 10 to 30 miles contains ozone which stops the sun's ultra violet rays from reaching the earth, where they would burn and utterly destroy all forms of life.

Without this protection of the atmosphere, the earth would be bombarded by meteorites and pitted with craters similar to those on the moon.

2. LAYERS OF THE ATMOSPHERE

An examination of the atmosphere reveals four distinct layers with large differences in temperature.

Ionosphere: beyond 50 miles
Ozonosphere: from about 15–50 miles
Stratosphere: from about 8–15 miles
Troposphere: from ground to about 8 miles.

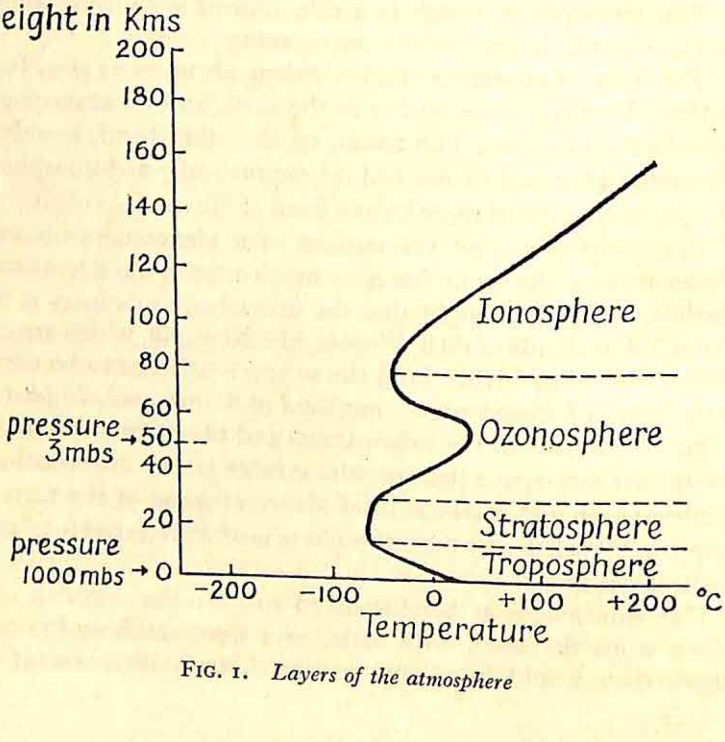

FIG. 1. *Layers of the atmosphere*

In the troposphere the air is constantly changing. The upper limit of this layer, known as the tropopause, is highest over the equator (50–60,000 feet) and lowest over the poles (20–25,000 feet). Its height also varies with the season and over Great Britain in summer it is between 35–45,000 feet and in winter 25–30,000 feet. The drop in temperature with height – that is the *lapse rate* – varies with each airstream, but on average it is about $3\frac{1}{2}$° F. (2° C.) for every 1,000 feet, giving a mean temperature of −60° C. at the tropopause. The stratosphere extends from the tropopause to about 80,000 feet, in which the temperature stays more or less constant. In the ozonosphere (from about 80,000 feet upwards) there is a rapid increase in temperature caused by the interception of the sun's short wave radiation by ozone gas. The temperature falls to −35° C. at 50 miles, only to rise again in the ionosphere.

Ions, particles carrying an electric charge, are produced in large numbers by the sun's short wave radiation. Layers of greatest concentration are found at heights of 60, 140 and 220 miles.

3. AIR

The air around us contains, in the main, nitrogen (78%) and oxygen (21%). Carbon dioxide is one of the many other substances which make up the remainder.

As we breathe, oxygen is extracted from the air to provide fuel for our bodies. Without it we could no more live than a candle flame can burn beneath a bell jar. We exhale carbon dioxide. Under the influence of sunlight, green vegetation uses this carbon dioxide, replacing it with oxygen. This is known as photosynthesis.

Nitrogen, which is vital to the growth of all plants and animals, is torn from the air by the violence of a lightning flash to form nitrogen oxides and ammonia which are carried into the earth by the rain, thereby bringing fertility to the soil.

Air surrounds us on every side, filling every nook and cranny. It is found in the deepest mine or on the highest mountain. If you fan your face with a piece of card you can feel air on your skin, though you cannot see or smell it. It is real. A so-called 'empty' jar is really full of air.

Push the mouth of a jar straight downwards into a bowl of water and notice how little water is able to enter the jar. Air is keeping the water out. Tilt the jar and see how bubbles of air escape, rising through the water to break at the surface. The more air released, the higher the water rises inside the jar.

Using two inverted jars under water, catch the bubbles of air from one jar in the other jar and note the changes in the levels of the water inside the jars.

Compared with the 8,000 mile diameter of the earth, the depth of the 'ocean' of air in which we live and move is of film-like thinness. Although there is some air at a height of more than 100 miles, even at 60 miles it is thinner than the 'vacuum' found inside an electric light bulb.

Above the surface of the earth, the air rapidly thins out. On a high mountain the air is so much thinner than at ground level that a climber has to breathe far more rapidly in order that his body may get enough air for its needs. More than three-quarters of the total mass of air in the atmosphere is found within a height of nine miles above the earth's surface.

4. THE TEMPERATURE OF AIR

The temperature of the air in which we live is an important factor in our lives. What we do, what we wear and even what we eat are influenced by how warm or how cold the weather is. More than that, the temperature of the air in other parts of the world as well as our own is directly responsible for all the various aspects of weather that we experience.

Before studying how weather is caused it is important to know of the three ways by which air in the atmosphere is heated to a temperature which makes it possible for us to live on this planet.

The source of all our heat is the sun. The radiation of heat from the sun, known as *solar radiation*, heats the surface of the earth without heating the air surrounding it. This air is heated from *below* by contact with the warmer surfaces of land and sea. This second process of passing heat is known as *conduction*.

Thirdly, air that has been heated begins to rise. In rising it heats the air above it. This process is known as *convection*.

Like all gases when they are heated, air becomes less dense. That is to say, any amount of heated air occupies more space than the same amount of cooler air. In short, the air itself becomes thinner.

It can, therefore, be easily understood that a cubic foot of warm air actually contains less air than a cubic foot of cold air.

5. THE WEIGHT OF AIR

It is difficult to realise, as we stand looking up into a clear sky, that the air around and above us has weight, but in fact it weighs millions of tons. On average, every square inch of the earth's surface is pressed upon by fifteen pounds of air.

The total weight of it pressing on each one of us is many thousands of pounds. We do not notice this, because the blood and tissues inside our bodies are saturated with air exerting an equal and opposite force outwards. For the same reason fish are not crushed by the combined weight of air and water above them.

Weigh a football which is full of air at normal pressure, then blow it up hard. The increase in weight will convince you that air has weight.

The atmosphere exerts a pressure at any point, in the air or on the ground, because of the weight of air above that point. In meteorology this pressure is measured in metric units – in *millibars* (abbreviated: mbs.). The following experiment clearly illustrates the pressure of the atmosphere.

Boil a little water in a petrol can. This will drive out nearly all the air. Screw down the lid and wait for the steam inside the can to condense. The can should collapse. The result is not surprising when you calculate the pressure involved. A one gallon can measures approximately 11 ins. × 7 ins. × 4 ins. The surface area is 298 sq. ins. on each of which is a pressure of 15 lbs. (equivalent to a total weight of nearly 2 tons).

A vacuum cleaner works on the same principle. An electric fan pushes the air out of the cleaner, thus creating a partial vacuum inside. The outside air is forced in to fill this vacuum, entering through the nozzle, carrying dirt and dust with it.

The limpet clinging firmly to the rocks, like the 'sucker' type of car mirror, depends on the pressure of the air pushing against a partial vacuum.

A simple experiment you can do for yourself is illustrated in Fig. 2. Remove the glass top from the metal rim of a Kilner jar and replace it with a piece of rubber sheeting. Rinse out the jar with hot water; this will drive out some air and warm the rest. At once screw on the lid. As the jar cools, water vapour and air contract, and the higher pressure outside causes the rubber sheet to bulge inwards.

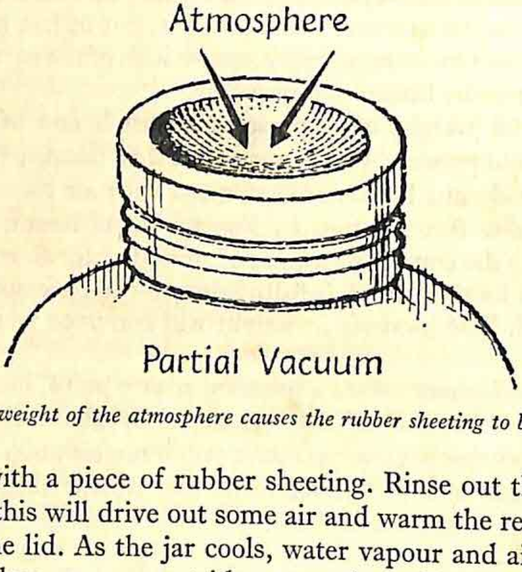

FIG. 2. *The weight of the atmosphere causes the rubber sheeting to bulge inwards.*

Whether the jar is upright, upside down or on its side, the depression of the rubber sheeting will not change, because, at any one place, air *presses with the same force in all directions*.

That air pressure can be exerted upwards is demonstrated by the operation of parachutes. Air, pushing upwards against the inside of the large canopy of a parachute is sufficient to allow men and machines to drop slowly to the ground.

We are now considering the lowest layer of the atmosphere, the troposphere, which reaches from the earth to a height of eight or nine miles. Beyond this, air is very thin, or rarified, and aircraft have to be specially designed and powered to fly in these conditions.

6. AIR IN MOTION

Within the troposphere, air is not evenly distributed over the surface of the earth and there is constant distribution of air to even out these differences. As a result, the air moves, i.e. winds are created. Surface winds tend to reduce the pressure differences, though these are constantly recreated in the upper atmosphere.

As soon as one difference is righted, new ones appear and out of the ensuing battle 'weather is born'.

You will have noticed that if you seal the valve of a bicycle pump with your finger and push the handle down, it is possible to make the air inside the pump take up far less room. The more the air is compressed, the harder it is to push the handle because compressed air is heavy, or more correctly, dense. Similarly, when a considerable amount of air collects in one area in the troposphere, the lower layers of air are compressed by the extra weight of air above them and become heavier.

These changes in the weight, or pressure, of air above a place are an important factor in the making of weather.

7. MOISTURE IN MOTION

Oceans, lakes and rivers cover much of the earth's surface with water. Clouds consist of droplets of water suspended in the air. Sometimes these clouds cause water to fall on the earth in the form of rain or snow, bringing moisture to the vegetation and soil, and filling the lakes and rivers.

It is important to realise that the water in the clouds is taken from the surface of the earth, from the vegetation and soil as well as from the oceans and lakes. Air is responsible for collecting and distributing it. There is always moisture in the air. Sometimes it can be seen as clouds or fog but even when the sky is clear, the air contains moisture in the form of invisible vapour.

Water, then, can exist in three very different states: as a liquid in water droplets, as a solid in ice or snow particles, as a gas in water vapour. Within the atmosphere, water is constantly changing from vapour to liquid or gas and back again. It also circulates constantly between air and ground and sea and plants and animals.

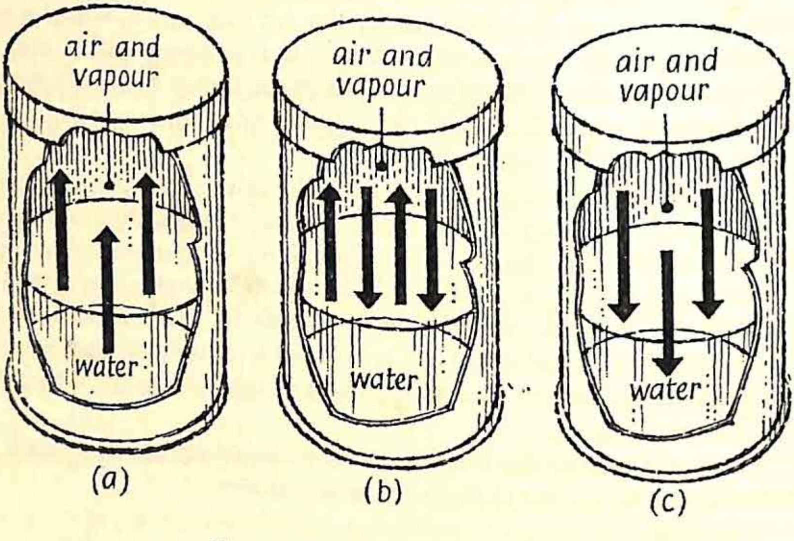

FIG. 3. *Evaporation and condensation*

(a) Evaporation – molecules escape from water into the air.
(b) A state of balance when the air is saturated with water vapour.
(c) Condensation – molecules escape from air back into water.

Miraculously, not one drop is ever lost!

The change from liquid water to water vapour is called *evaporation*; the change from water vapour to a liquid is known as *condensation*.

When steam rises from boiling water, the water is evaporating. If you leave water in a saucer long enough, that too will change from liquid to vapour and disappear.

On the other hand, in a closed bathroom after a hot shower, the cooler windows and mirror will become misty and moisture will settle on the walls. The water vapour is then changing back into liquid, or condensing. If a little water is poured into a tin and the lid put on, some of the water will escape from the surface into the air above it to become vapour. Some vapour may re-enter the water. These two processes, evaporation and condensation, will go on side by side and at any given temperature will eventually reach a state of balance. This means that the air above the water has reached the limit of the amount of water it can absorb. The air is 'saturated' with water vapour. If the tin is warmed, the balance is upset and it is found that more water evaporates. If the tin is cooled, water settles on the sides, that is, the water vapour condenses.

Air distributes water over the earth by means of these two processes.

8. THE EARTH AND THE ATMOSPHERE

The earth rotates about its axis once every 24 hours. A point on the equator, where the surface of the earth is farthest from its axis, travels at over 1,000 m.p.h. As the lines of latitude become shorter, the speed decreases until at the poles it is negligible. London in latitude 51° N. moves at about 650 m.p.h.

The atmosphere surrounding the earth is pulled along and rotates with the earth from west to east. If the speeds of the earth and the atmosphere are the same, from the point of view of somebody on the earth the air appears still – there is no wind. If the air moves to the east faster than the earth below it (giving a westerly wind), that air will be forced towards the equator, that is, to its right (in the northern hemisphere), until it reaches a latitude where the earth is moving at an equal speed. Similarly, if the air is moving eastwards more slowly than the earth below, to somebody on the earth the wind appears to be blowing from the east. This air will be forced nearer to the poles to find the surface of the earth moving at a similar speed. It is deflected to its right.

The rotation of the earth causes all winds to be deflected, in the Northern Hemisphere, to the right of its original direction.

The purpose of this chapter has been to introduce the simple physical principles that are always at work in the atmosphere. The interaction of these basic principles result in the varying conditions of air and moisture known as weather.

Succeeding chapters examine these principles in greater detail and explain their effects one upon the other.

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2 Temperature and its Effects

1. SOLAR RADIATION

The earth receives its energy – light and heat – from the sun by radiation. If you sit in front of a fire, you can feel its heat on your skin but the air between you and the fire remains much cooler. If someone else stands in between, you immediately notice the loss of heat. This is radiant heat or more simply radiation. The sun emits heat and light in waves of energy which pass through the 93 million miles of space before reaching the earth and its atmosphere. It is the atmosphere – the thin film of air surrounding the earth – which modifies the sun's radiation, as a result of which life is made possible on the earth.

The waves of the sun's radiation are absorbed or reflected by solids and liquids but pass practically unhindered through gases.

It has been estimated that half of the earth's surface is covered with cloud at all times. The water droplets in the upper surfaces of these clouds are responsible for reflecting away from the earth about two-fifths of the solar radiation. More solar radiation is reflected away by the snow and ice, and some by the oceans and even a little by the dry land: This loss by reflection is known as the earth's *albedo*.

In addition, the incoming radiation is still further reduced by (*a*) *absorption* of some of the sun's energy by concentrations of ozone gas in the upper atmosphere, and (*b*) *scattering* of the sun's radiation in all directions by the minute particles of smoke and dust found in the lower layers of the atmosphere. In total, less than half of the incoming solar radiation passes through the atmosphere to be absorbed by the earth's surface.

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2. CONDUCTION AND CONVECTION

A molecule is the smallest particle into which a substance can be divided without chemical change. The molecules of every substance are in constant motion, and the heat of a substance is a measure of the amount of motion – the energy – of its molecules.

When the end of a poker is put in the fire, the heat causes the molecules to vibrate more vigorously at that end. These vibrations agitate neighbouring particles, increasing their vibrations, until heat has passed from particle to particle throughout the poker. Conduction is most important in solid bodies in which the molecules are densely packed and unable to move bodily from place to place.

Metals are easily the best conductors of heat. Liquids (except liquid metals) are poor conductors and gases, such as air, are very poor indeed.

One of the main purposes of clothes is to insulate the body. They should therefore be poor conductors of heat. The value of wool in this respect lies in the amount of air trapped within the fabric. The furs of animals and the feathers of birds give good protection against the cold by a similar use of air. The groundsman protects his precious ground with a layer of air held together by loose-lying straw and nature protects the young shoots of plants from a severe frost by a coating of snow in which air abounds between the crystals.

In very many ways the atmosphere is like a garment preventing us from burning by day and freezing by night.

Soil, a mixture of gravel, sand and silt and a high proportion of air, is a bad conductor. Thermometer readings of the soil in a garden at depths of 2 ins., 6 ins., and 12 ins. show that, in sunshine, although the surface may be quite warm, it is quite cool at lower depths. Experiments with different kinds of soil, heavy as well as sandy, show how much hotter the surface of a sandy soil becomes because it does not contain so much air.

Nor, in cold weather, is heat easily conducted away from under-lying soil. For this reason most 'stop-taps' are placed about 12 ins. below the surface of the ground, beyond the reach of frost.

In liquids and gases, the molecules are free to move from place to place within the fluid. When a liquid is heated from below, it expands, becomes less dense and rises. Colder, heavier liquid sinks on the outside to be heated and, in turn, rises until all the liquid boils.

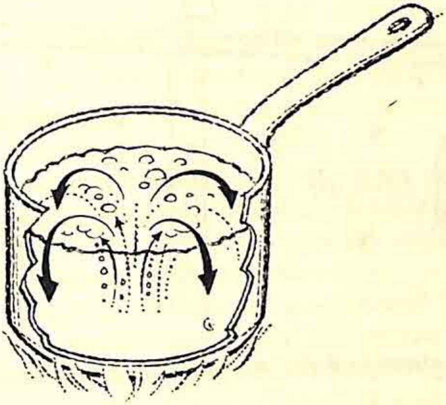


FIG. 4. *Convection currents*

When you boil water in a saucepan, the particles of water touching the bottom are heated by conduction. The warmed water is carried upwards, in bubbles, by convection currents.

3. HEAT IN LAND AND WATER

Imagine you are on the sea-shore on a calm, sunny day. The sand and the air are very warm. You bathe but find the water comparatively cold. Both the land and the sea have received similar amounts of heat but their temperatures are very different. Why is this?

On average the specific heat of land is about one fifth that of water. This means that it takes five times as much heat to warm a mass of water the same number of degrees of temperature as it does to warm an equal mass of land by the same amount.

As the temperature of the land rises, the particles of air in contact with the ground are warmed and convection currents take the warmer air aloft in a way similar to the rising of bubbles of hot water in a saucepan.

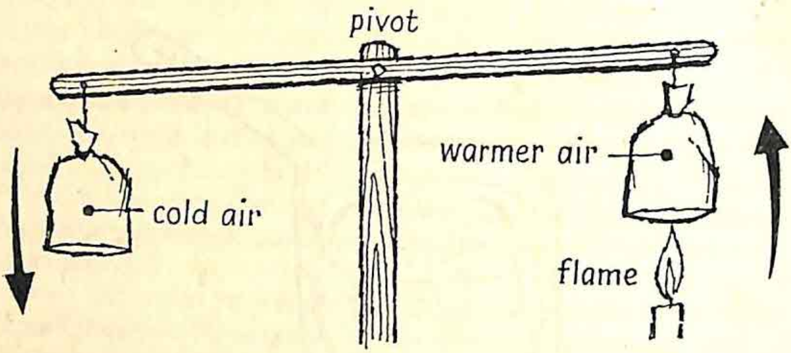


FIG. 5. *Experiment to show that warm air is lighter than an equal volume of cold air*

After a few hours, the air over the land is warmed to a height of about 1,000 feet. Being warm, it has expanded and become less dense. There is a slight drop in air pressure over the land compared to that over the sea. To preserve the balance, air flows at ground level from the sea in over the land to replace the rising air. At higher levels the circulation of air is completed by air flowing in the opposite direction towards the sea.

In this way a small local wind known as a *sea breeze* is created at ground level. In Britain it is usually a light wind of about 10 m.p.h. and can extend inland from a few miles to over 20 miles. In the Tropics, with greater temperature differences, these winds are usually much stronger.

The reverse happens at night when the temperature of the land has fallen below that of the sea. Then the air over the sea is warmed

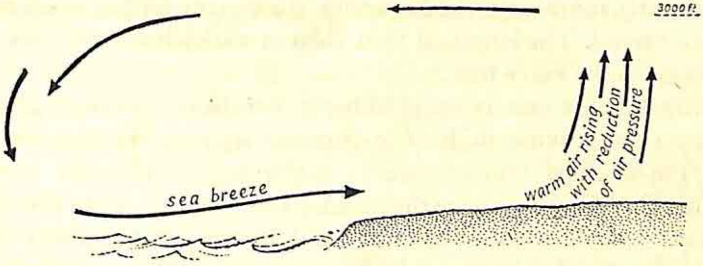


FIG. 6. *A sea breeze*

and rises to be replaced by cooler air flowing from the land towards the sea. This circulation is known as a *land breeze*.

Sailors, in hot climates, can often identify their position by the particular odour brought to them by this off-shore wind.

A few hours sunshine on a strip of land and sea can give rise to a difference of a few degrees of temperature and a difference in air pressure sufficient to cause a slight breeze.

The effect of large land masses, such as Europe and Asia or North America, and large oceans, such as the Pacific and the Atlantic, in creating vast differences in temperature, pressure and wind can easily be appreciated.

4. HEATED BY THE SUN

The main cause of temperature differences does not lie in the distribution of land and water over the earth, but in the amount of solar radiation (or to be brief, *insolation*) received by the various parts of the world.

When the sun is overhead, the rays strike the earth at right angles and their heat is concentrated in as small an area as possible and the rise in temperature is great.

When the sun's rays fall slantingly on the earth's surface, the same amount of heat from the sun is spread over a much bigger area and the rise in temperature is less.

Doubtless you have noticed that when the sun is low in the sky in the early morning or late evening, the heat from the sun's rays is less intense. The length of your shadow varies inversely with the strength of the sun's heat.

Although the sun is never directly overhead in Great Britain at any time, around midday in summer its rays are less oblique and the average temperature is much higher than in winter. Within the Tropics, where the midday sun is always high, the sun's rays are intense, shadows are small and the temperatures very high. From the equator to the polar regions, where the rays from the low sun give little heat except around midsummer, there is generally a gradual drop in temperature.

HOW HOT IS HOT WEATHER?

In Britain the two warmest months of the year are July and August. In the years 1921–50 the average maximum temperatures were:

	July	*Aug.*
Braemar	63·7° F.	62·2° F.
York	70·0° F.	68·6° F.
Cambridge	72·1° F.	71·3° F.
Kensington Palace (London)	72·7° F.	72·0° F.
Penzance	67·3° F.	67·7° F.

Notice the cooling effect of the westerly winds in summer.

The highest recorded temperature in the British Isles is 100·5° F. on 22nd July 1868, at Tonbridge.

The highest temperature in the United States is 134° F. on 10th July 1913, at Death Valley, California. The highest in the world is 136·4° F. on 13th September 1922, in Tripolitania, North Africa.

5. CHANGES IN AIR TEMPERATURE

Air temperature is measured by a *thermometer* which is in the shade and positioned 4 feet above the ground, away from buildings, and well ventilated.

The temperature of air over Britain at any time depends upon its source and its journey. Air from Siberia in winter is still cold when it reaches us, just as air from the sub-tropical regions is warm. Later, we shall examine the various air masses which visit this country.

At this stage it is convenient to consider the changes that take place in the temperature of the air in a period of 24 hours – so-called *diurnal* changes.

You will remember that air is warmed from below by contact with the ground (conduction). Convection currents carry the heat into the air where it mixes with the cooler air until the temperature of the whole layer is slowly raised.

As the ground is heated by the sun's rays, the increase in temperature of both the ground, and the air above it, will be greater

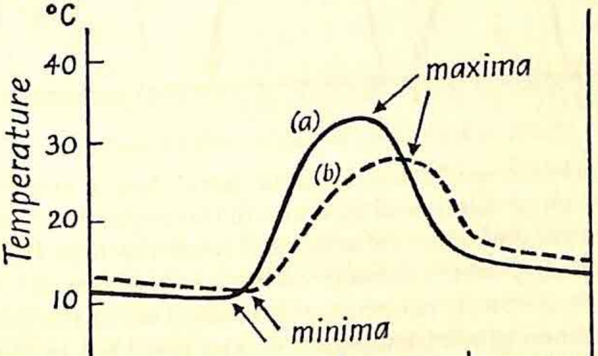


FIG. 7. *Changes in the* (*a*) *ground temperature,* (*b*) *air temperature, on a cloudless and windless day*

when the sun is high in the sky and there are no clouds to reflect the rays away from the earth. Fig. 7 shows two graphs (*a*) the changes in ground temperature and (*b*) the changes in air temperature in a 24-hour period.

Note that the lowest ground temperature is about half an hour after sunrise. This is because, up to that time, the earth is losing more heat by radiation than it is receiving from the oblique rays of the low sun. Throughout the night, of course, there has been a constant loss of heat by radiation.

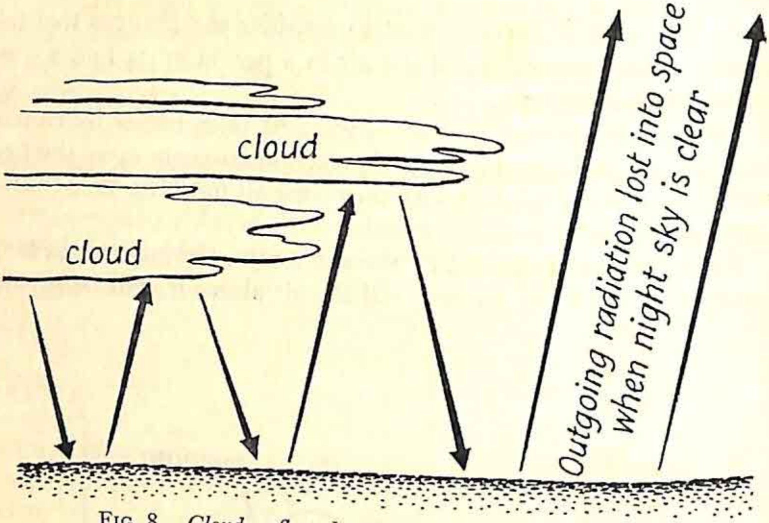


FIG. 8. *Clouds reflect the earth's radiation back to earth.*

The main factor which reduces the earth's loss of heat to space is the presence of clouds and moisture in the air, as these are able to intercept the outgoing radiation and send the heat back to the earth. Usually, frost is unlikely when there is a layer of low cloud.

The maximum air temperature is reached about two hours after the maximum ground temperature. The rapid fall in the ground temperature after two in the afternoon shows how much less intense the heat from the sun's rays becomes as they meet the earth more obliquely.

3 Water in the Atmosphere

1. EVAPORATION AND CONDENSATION

Nature needs no plumbing in order to distribute water over the face of the earth. The changing temperature of air is the vital factor.

The rate and the amount of evaporation that takes place from the surface of the earth depends on:

(*a*) The higher the temperature the more water vapour the air can absorb before it becomes saturated. Evaporation is also more rapid at higher temperatures.

(*b*) If there is a strong wind constantly changing the air above a surface, there is less likelihood of the air reaching saturation and more evaporation will take place.

(*c*) The amount of evaporation depends on the amount of water vapour already in the air. When the air is saturated, no more evaporation will take place unless there is a rise in temperature.

Most housewives recognise these factors in everyday life and hope for warm, dry and windy conditions on washing day.

Warm air can hold more water vapour than cooler air. If air that is already saturated is cooled, some vapour will condense back into liquid water. Although air in the atmosphere can be cooled by mixing with colder air or by coming into contact with a colder surface of land or sea, by far the most common and important means by which the temperature of the air is lowered and condensation takes place to produce clouds is by expansion. When air expands, the moving molecules are torn apart and energy is required to do this. This energy is taken from the motion of the molecules themselves; they are slowed down, which means that there is a drop in temperature.

Making Cloud

Rinse the inside of a large bottle with water to moisten the air and leave some water in. Fit a cork through which passes a football valve. Pump in air, preferably that is already damp and cool. Pump in just enough air to build up the pressure, ensuring expansion of the air when the valve is released. Release the cork and a mist or fog will form inside the bottle.

The sudden reduction of pressure allows the air inside the bottle to expand. Consequently it is chilled and some of the water vapour in it is thrown out to form a cloud of minute droplets of water throughout the air.

Refit the cork and valve and pump in air. You will notice that the cloud disappears or evaporates and the temperature of the air inside the bottle increases.

Repeat the experiment but introduce a little smoke into the bottle and you will see that the cloud or fog is much thicker. This is because there are more *nuclei* on which the water vapour can more easily condense.

2. RELATIVE HUMIDITY

As air becomes more moist, that is, as it approaches saturation, we say its relative humidity has increased.

The measure of *relative humidity* (R.H.) is worked out as a percentage by means of this formula:

$$\text{R.H.} = \frac{\text{amount of water vapour present in air}}{\text{maximum amount of water vapour the air could hold at the same temperature}} \times 100\%$$

When air is saturated, the R.H. is 100%.

When air is warmed its Relative Humidity falls and when air is cooled its Relative Humidity rises.

Condensation nuclei are the minute particles around which water droplets form. Their existence and importance were first demonstrated in 1880 by J. Aitken, a British physicist. Particles of salt taken into the air by sea spray and various products of smoke and dust are common nuclei, some of which are always present in the atmosphere, even at heights of many miles. It can be appreciated that the quantity and nature of these particles vary from place to place. Over a big city there may be large concentrations of soot and smoke. This is why fog in a city, consisting of very small droplets of water closely packed together, is usually more dense and dirty than a fog in its suburbs.

3. LATENT HEAT

If you pour methylated spirit on to your hand, it evaporates quickly and your hand feels cold. Similarly, if you allow soaking wet clothes to dry on your body, you shiver with the cold – in fact you are colder than if you were without any clothes at all. In both cases, it is the evaporation of the liquid which causes your skin to feel cold.

When evaporation takes place, the fastest moving molecules escape from the liquid into the air above. Now the temperature of a substance is but a measure of the total energy of its molecules. The more molecules that are lost in evaporation, the lower will be the temperature of the water left.

In the atmosphere, when evaporation takes place, this heat, known as *latent heat of vaporisation*, is taken from the evaporating surface and the air in immediate contact with it.

When water vapour condenses and returns to liquid water, the latent heat is liberated and warms the surrounding air.

4. DEW POINT AND CONDENSATION

Consider the changes that take place in a small mass of air which is warmed at the earth's surface on a sunny day. Some of the warmest air rises like a large bubble. The higher it goes the more it expands because there is less atmosphere above pressing on it. The more it expands the lower its temperature becomes and the higher is its relative humidity. If it continues to rise, it will reach a temperature when it is saturated with water vapour. (R.H= 100%.) This temperature is known as the *dew point*. If the air rises beyond this level the water vapour will condense and small droplets lets of it will form around suitable nuclei always present in the air.

The level at which condensation begins is called the *condensation level*. Cloud which forms in air which was made to rise by being heated over the ground or sea is called *convection cloud*.

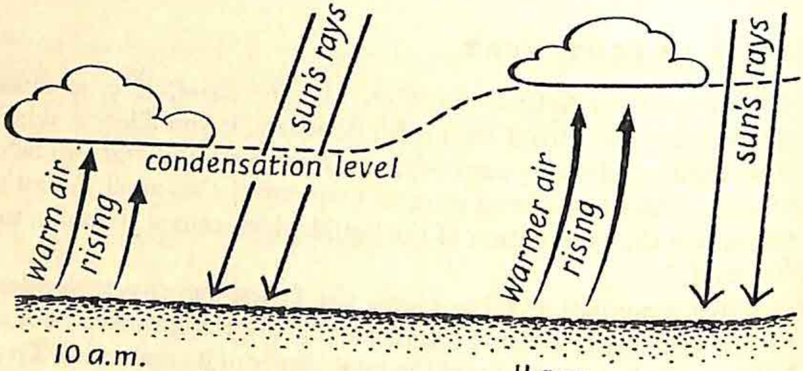
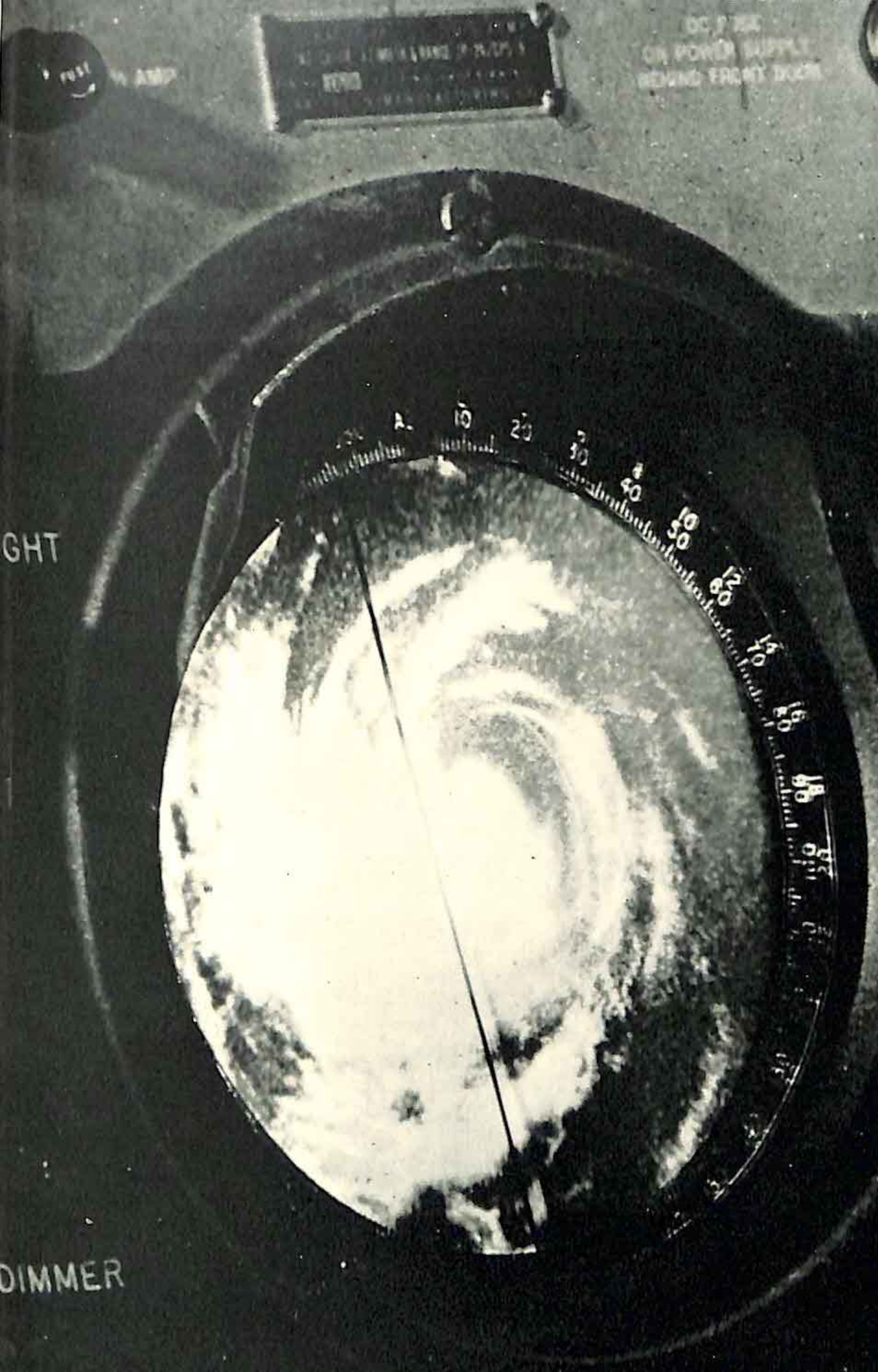
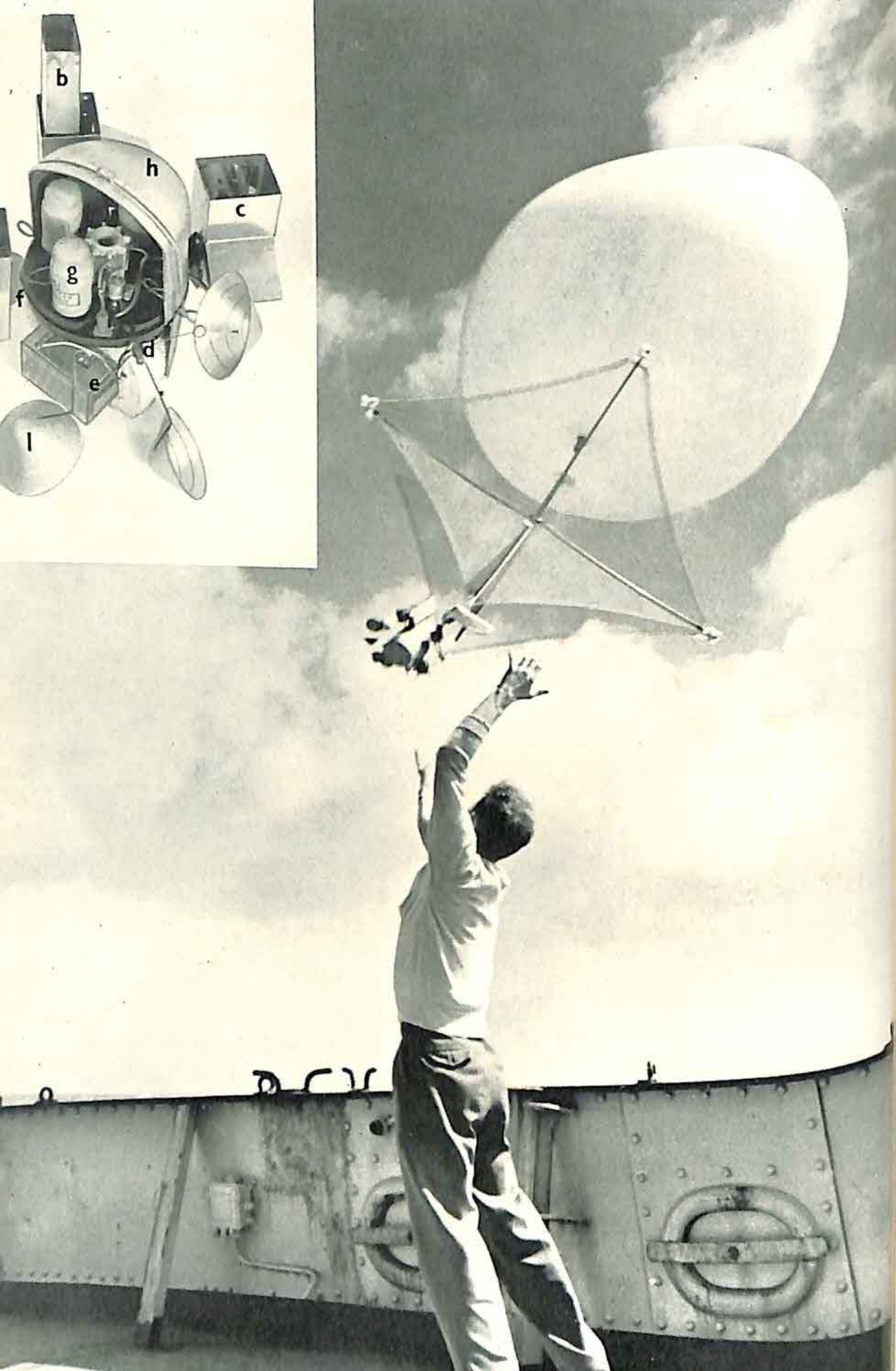


FIG. 9. *Condensation level is raised as the heat from the sun increases*

FORMATION OF A HURRICANE SEEN ON A RADARSCOPE



FUSE
AMP
DC FUSE
ON POWER SUPPLY
BEHIND FRONT DOOR
GHT
DIMMER
10
20
30
40
50
60
70
80
90


b
h
c
g
f
d
e
l

Air may also be forced to rise past the level at which clouds will form in it by passing over hills or even by overriding other air which is colder and denser.

The height at which these clouds will begin to form depends on the relative humidity of the air at ground level, before it starts its upward journey. The moister it is at the outset, the sooner will it be cooled to saturation.

The flat, horizontal bases of the clouds mark the condensation level over an area at a particular time. As the air temperature near the ground increases during a sunny day, fresh bubbles of warmer air rise to feed and build up a cloud. As this air is warmer when it starts its journey upward, it causes the bases of the clouds to rise higher during the heat of the day.

5. INSTRUMENTS

The *wet and dry hygrometer* is used to measure the humidity of air near the ground. It consists of two thermometers, round the bulb of one of which is a twist of muslin from which hang a few strands of cotton wick. The ends of the wick absorb water (distilled water is preferred) from a container and keep the muslin sleeve around the bulb of the thermometer moist. The other thermometer measures the temperature of the air.

As the water evaporates from the muslin, latent heat is taken from the bulb of the thermometer so that the mercury contracts and the temperature, shown on the scale, falls. The drier the air, the more evaporation will take place and the greater will be the difference between the readings of the two thermometers. This difference is known as the *depression* of the *wet bulb* thermometer. In fog, the air is already saturated and the two readings will be the same. From the information gained from a hygrometer, it is possible to estimate the likelihood of fog or cloud forming, the probable extent of cloud if cloud does form, and the height of its base.

The *hair hygrograph* makes a continuous record of the relative humidity of the air. It depends on the fact that human hair, freed

LAUNCHING A RADIO-SONDE FROM AN O.W.S. 'WEATHER REPORTER' (*inset*) SECTIONAL VIEW OF RADIO-SONDE (For key see Notes on the Photographs, pages 123–4) from grease and fat by boiling in caustic soda or potash, increases in length as the humidity of the air increases and contracts when the air is drier. The varying lengths of a small bundle of hairs, through a system of levers, cause a pen to move up or down on a slowly revolving drum.

WATCH THAT STORM

During the Second World War it was discovered that ice crystals, cloud droplets and raindrops reflected radar beams, causing bright spots to appear on the radarscope, giving the direction, distance and intensity of the clouds. Special sets with a 400 mile range were developed for the meteorologists. Their value lies in tracking severe storms, especially over uninhabited land or sea, and in planning safe flight routes.

6. DEW, FROST, FOG AND MIST

Dew, hoar frost, fog, mist all have much in common in their formation.

We have already seen that the night temperatures of the ground and of the air near it are lowest when (*a*) the sky is free of clouds which re-radiate heat back to the earth and (*b*) when there is very little, if any, wind so that the same air remains in contact with the cooling ground. A stronger wind means that the air is being changed and also mixed with warmer air above.

Moist air requires little cooling before the water vapour condenses.

DEW

As the ground cools the air immediately in contact with it is chilled and if the temperature of the air falls below its dew-point, drops of water called *dew* form on the tips and edges of blades of grass and other rough surfaces.

You may have noticed that dew appears on the upper surfaces of grass and plants. It is rarely found below, nearer the ground or on bare soil. A few experiments with minimum thermometers (see Fig. 10) will show why.

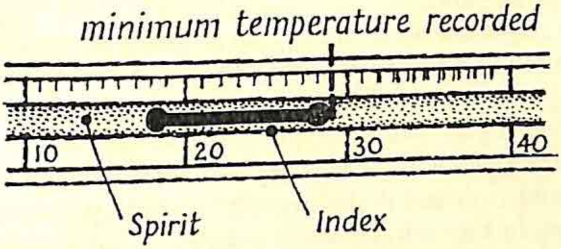


FIG. 10

Compare the readings when the thermometer is placed (*a*) level with the top of the grass, (*b*) in between grass, (*c*) on bare soil, (*d*) above and below a plant, bush or tree.

Pockets of air trapped between the blades of grass, under foliage and in the soil, form a non-conducting blanket which helps to prevent the surface of the ground from losing its heat. The ground is, as it were, insulated and kept warm by a thin layer of air. However, it should be noted that much of the moisture found on plants and grass is not dew but has been exuded from the leaves themselves by *transpiration*.

If the temperature falls below 0° C. (freezing point), after dew has been deposited, it is likely that the dew will freeze into white ice crystals known as frozen dew or silver frost.

FROST

This occurs when the temperature falls below 0° C., but it is necessary to distinguish between a frost caused by cold winds and one caused by radiation which is the loss of heat from the ground under clear skies at night. In the first case, air with a temperature below freezing point is brought by the wind. In the second case, the air is cooled from below by being in contact with the ground and the cooling proceeds upwards. A ground frost occurs when the air near the ground is below freezing point; an *air frost* is present when the temperature measured at a height of 4 feet from the ground is below freezing point.

Since a single late air frost can ruin a whole fruit crop if the trees or bushes are in blossom, it is easy to understand the importance that fruit growers attach to frost warnings. In planting an orchard, they choose, if possible, a site which is protected on its north and east by natural wind barriers. They also use sloping ground so that colder, heavier air can drain away down the slopes away from the trees. Even in this country some growers, following the example of their American colleagues, light fires when conditions are critical. The heat and the smoke spreading over the trees are surprisingly effective in preventing frost. Frosts are associated with clear night skies, especially (but by no means only) in winter, and also with a cold Arctic or continental air stream covering the country with air which is already cold and dry.

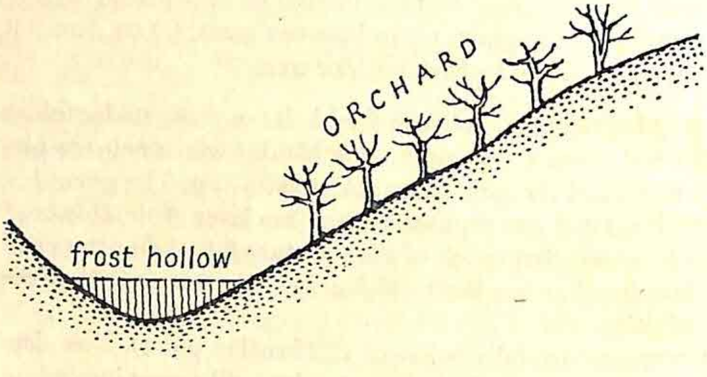


FIG. 11. *Colder air drains down slope into the hollows.*

HOAR FROST

If the night temperature reaches 0° C. without any dew being deposited because the air is relatively dry, any condensation of water vapour at lower temperatures will usually result in the formation of soft, white ice crystals known as hoar frost.

FOG

Following the deposit of dew, if cooling of the ground continues, more and more air near the ground will be chilled and become saturated, and droplets of water will form around nuclei present in the air. Thus a low fog, which is a cloud on the ground, is formed. Once fog has started to form it often grows upward more rapidly because heat is radiated from its upper surface. Gentle turbulence within the air also helps to spread the fog upwards.

Notice how a road is protected for many hours by a canopy of leaves overhead while adjacent fields are covered with thick fog.

You will have noticed too how mist or fog often starts first in sheltered, damp valleys and hollows. This, no doubt, is not only caused by the extra humidity of the air and the sinking of cooler air into the hollows, but also by the absence of strong wind. This type of fog – *radiation fog* – is associated more with open countryside than it is with cities where the buildings and fires help in keeping the temperature of the air above its dew point.

However, the fogs found in and near cities are more dense because of the relatively great amount of soot and smoke in the air. It is possible for water vapour to condense on smoke nuclei even when the air is not saturated. These smoke fogs – popularly called 'smogs' – can be most persistent and dense enough to make daytime as dark as night. They develop over industrial Britain mainly in winter when the weather is dominated by an anticyclone. Apart from clear skies, little wind and low night temperatures, an anticyclone prevents air from escaping upwards.

Anticyclones are areas of sinking or subsiding air and just as the temperature of air drops as it expands, so its temperature rises as the air sinks and becomes more dense. This often results in the air some few hundred feet above ground having a higher temperature than that on the ground. A *temperature inversion* is created which acts like a ceiling over the ground. All the soot, dust, smoke, chemical fumes, car exhaust gases and other poisons produced by city life are concentrated and imprisoned over a city and its inhabitants. This 'smog' attacks their buildings, clothes, furniture and lungs and leaves in its wake grime, soot, bronchitis and death.

In order to avoid these conditions, 'smokeless zones' are a necessity.

MIST

Although many of us think of mist as the clean wet product of condensation over the countryside, and fog as the smoky, sulphurous condensation over towns, the meteorological definitions distinguish them on visibility alone.

If the visibility – that is, the greatest distance at which an object can be clearly identified – is less than 1,100 yards (one kilometre), there is a fog. If greater than 1,100 yards there is a mist. Note that *haze* is caused entirely by dust and smoke particles in the atmosphere – no water droplets are present.

Fog usually disperses when the heat of the sun warms the ground enough to cause the fog to lift from the ground to make low clouds which soon evaporate as the temperature of the air rises. Usually the wind increases under these conditions and it assists the dispersion by mixing the fog with warmer air from above.

LONDON FOG (5th to 8th December 1952)

London is well known for its fogs but the effects of one fog were more severe than any previously recorded.

Weather Situation An anticyclone was stationary over southern England. A trough of low pressure to the West of Ireland was making slow progress towards the British Isles. A temperature inversion, that is, a layer of warmer air overlying a layer of colder air, was produced which stifled the vertical movement of air. Fog became widespread over many parts of England but in the Lower Thames Valley and over Greater London it was exceptionally dense and persistent through the period.

The fog belt extended to a height of 250 feet on its southern boundary – the North Downs – and up to 400 feet on the Chiltern Hills to the north. It is interesting to note that Shooters Hill at 400 feet – well within the belt – was free of fog.

Atmospheric pressure (approximately)

5th Dec.	1036 mbs.
6th Dec.	1037 mbs.
7th Dec.	1038 mbs.
8th Dec.	1033 mbs.
9th Dec.	1027 mbs.
10th Dec.	1009 mbs.

Wind Almost a complete calm from the 5th to the 8th.
As pressure dropped winds increased.

Temperature Near freezing level.

Visibility In many places visibility rarely reached 22 yards from 5th to 8th.

Atmospheric Pollution The temperature inversion which extended from the ground to about 800 feet not only imprisoned the fog but also prevented the escape of industrial and domestic smoke fumes, resulting in high concentrations of pollution.

Smoke is measured in 'milligrams per cubic metre' (mgm/m^3)

and sulphur dioxide (SO_2) in 'parts per million'. Readings for Lambeth County Hall for this period are:

Dec.	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Smoke	0·49	0·61	0·49	2·64	3·45	4·46	4·46	1·22	1·22
SO_2	0·16	0·22	0·14	0·75	0·86	1·34	1·34	0·47	0·47

Deaths There were 3,500–4,000 deaths above the average for the first three weeks of December, 80–90% of these from respiratory and heart causes, but the victims were already sufferers from these diseases. The fog accelerated the worsening of their conditions.

Over 90% of them were people over 45 years of age.

60–70% of them were people over 65 years of age.

The number of deaths of children under 1 year was doubled.

Sickness There was a marked increase in sickness for the week following the fog. Sore throats, irritating coughs, breathlessness and bronchitis were the most common complaints.

Other London fogs which have caused sudden increases in the number of deaths, especially from bronchitis, occurred in:

9th–11th December 1873
26th–29th January 1880
2nd–7th February 1882
21st–24th December 1891
28th–30th December 1892
26th November–1st December 1948

Although on a much smaller scale fog or, more correctly, smog disasters have occurred in:

(*a*) The Meuse Valley, Belgium, 1st–5th December 1930, when more than 60 people died.

(*b*) At Donora, Pennsylvania in the United States, 27th–31st October 1948, when 18 people died and up to 2,000 were sick.

Like the London disaster these fogs occurred in industrial valleys and generally the victims were old with histories of ill health.

SEA FOG OR ADVECTION FOG

This is caused when warm moist air is carried by the wind from a warm sea surface to a cooler surface of water or land where the temperature is below the dew point of the air. The wind encourages the mist or fog to grow upwards.

The sea fog that rolls in over the Cornish and southern coast from the surface of the Atlantic has been formed by sub-tropical, warm, moist air being cooled as it travels northwards towards Britain.

The east wind, too, sometimes brings fog when air, which has been warmed over the continent of Europe in summer, is cooled over the North Sea.

HILL FOG

When a moist air stream covers the country, the base of the clouds (condensation level) is low, so that hills and high ground are enveloped in cloud. To anyone on high ground this cloud is fog.

RIME

The droplets of water in a fog can sometimes remain liquid even at temperatures below freezing point. If they are carried by the wind and come into contact with an obstacle such as a tree, telegraph pole or garden fence, the droplets immediately freeze on the windward side, sometimes building up into large collections of white ice crystals when the frost and fog are very persistent.

4 Atmospheric Pressure

1. MEASURING AIR PRESSURE

We already know that air has weight, and that it exerts a pressure on any point on the ground or in the air. This pressure averages about fifteen pounds on every square inch of the earth's surface.

An essential factor in forecasting weather is a knowledge of existing atmospheric pressures over a wide area. Instruments which measure atmospheric pressure are called *barometers*.

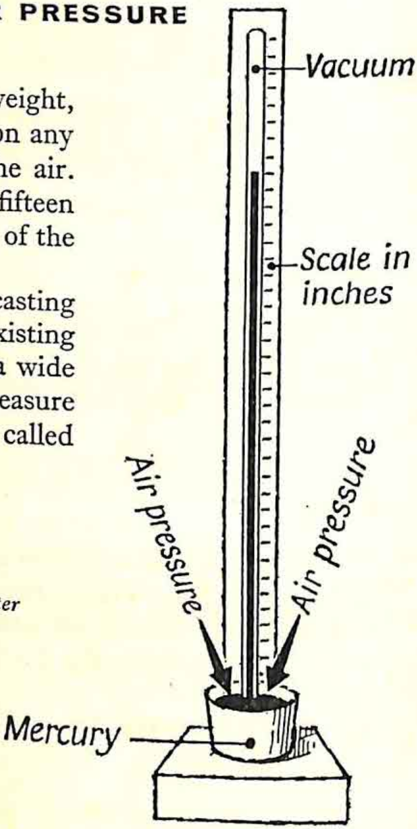


FIG. 12. *A simple mercury barometer*

In a simple MERCURY BAROMETER (Fig. 12) a column of mercury is balanced against the weight of the air. If the air around becomes denser, it presses more heavily, causing the mercury to rise in the tube.

Working 'Kew Pattern' barometers are more elaborate but operate on the same principle. Try to see one at a meteorological office or in a scientific laboratory.

Another type of barometer, the ANEROID, though generally not as accurate as a mercury barometer, is far less cumbersome, is easier to read and needs less attention. An aneroid barometer may be found in many homes and offices, and also in aircraft (where it is called an altimeter). It consists of a circular metal container from which most of the air has been removed. As air pressure increases, the sides of the container are pushed inwards and this movement is geared to a pointer which indicates a rise on a circular scale. A strong spring prevents the metal box from collapsing completely under the weight of the air.

Millibars (mbs.) are the standard unit for measuring the pressure of the air, but in Britain it is sometimes measured in inches: the length in inches of the mercury in the barometer tube above the level in the trough.

The average atmospheric pressure over Britain is about 1,013 mbs., which is equivalent to supporting a column of mercury about 30 ins. high.

As air pressure falls with height, a reading taken on a hill will be less than one taken at the same time in the valley below. So that readings may be compared, they are 'corrected' to give the pressure at mean sea level. The weight of the imaginary vertical column of air between the observation point and sea-level is calculated, allowing for the height and the density of the air. This weight is added to the reading.

Changes of barometric pressure are technically known as *pressure tendency*. A pressure tendency over the last three hours is of greater importance than the actual pressure. If the pressure has been falling, then the weather is likely to become more cloudy, wet and windy; if rising, an improvement is probable. Any sudden rise or fall is liable to be shortlived and will probably lead to an equally sudden opposite change, whereas a steady movement of the pressure usually leads to a prolonged spell of good or bad weather.

But air pressure is only one of many factors which must be considered before any clear idea of what is happening to the weather is gained.

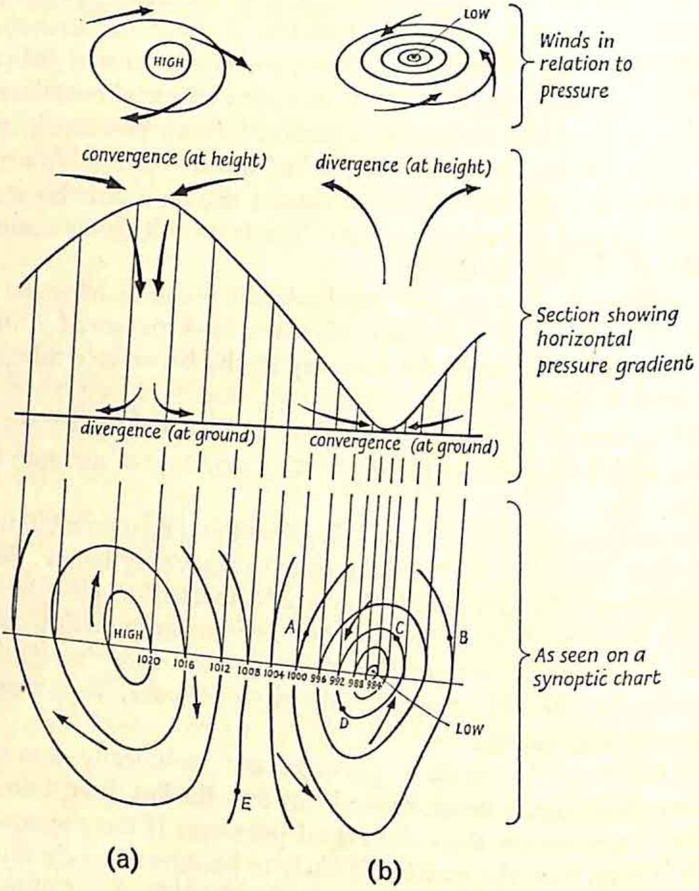


FIG. 13

2. ISOBARS

When a weather forecaster receives the corrected readings of atmospheric pressure from a large number of stations in the northern hemisphere, he plots them on a map. He then draws in the ISOBARS. These are lines which join places having the same mean sea-level pressure. These isobars, which look like contour lines (see Fig. 13) tend to form closed curves around the centres of either low or high pressure.

Isobars surrounding a depression (that is, a centre of low pressure) can be seen in Fig. 13b. At A, the air pressure is 1,000 mbs. and the isobar passing through A joins all places having the same pressure. The pressure at B then, must also be 1,000 mbs. At places C and D the pressure is 992 mbs. and at E 1,008 mbs.

The difference in the values of one isobar and the next on this chart is 4 mbs. We therefore say that these isobars have been drawn at 4-millibar intervals. Sometimes they are drawn at other intervals.

It is exceptional to find a depression centre of low pressure over Britain with a value at its centre below 940 mbs., or an anticyclone centre of high pressure with a value higher than 1,050 mbs.

The sections made through the areas of low and high pressure in Fig. 13 do not show the shape of the air; they show the horizontal distribution of pressure. The surface air in depressions will be less dense and in anticyclones more compressed. When the isobars are close together the pressure gradient is steeper. This means that winds are correspondingly stronger as air tries to move towards the centre of low pressure.

3. THE MAIN BELTS OF PRESSURE

In order to understand how the main belts of high and low pressure are produced, one must consider what is happening to the air at both ground level and high in the troposphere.

In the tropics, the air is heated strongly from the ground (and even fairly strongly over the warm seas) and strong convection currents carry the warm air up through the troposphere. Some of it rises to heights of 10 to 12 miles. At the top of its ascent it tends to drift away towards the poles. At the surface the rising air is constantly replaced by (originally cooler) air brought towards low latitudes by the *Trade Winds*. These Trade Winds blow from the north-east or east-north-east in the Northern Hemisphere.

The strong convection over the tropics and equatorial zone creates a belt of low atmospheric pressure – lower than over a belt around the earth just outside the tropics, about latitude 30°, where the Trade Winds come from.

At the other extreme, over the regions near the poles, and in the regions of very hard winter cold in Canada and Siberia, the very cold surface air becomes dense. More air becomes compressed into the bottom layers than over the warmer parts of the earth. Hence, there is a tendency for extra air to be amassed over the coldest regions, and for atmospheric pressure to be generally high there.

Over the broad range of latitudes between the equatorial belt of rather low pressure and the regions of generally high pressure near the pole and elsewhere in the cold zones there are two other zones:

(1) Prevailing low pressure over temperate latitudes, especially just outside the Arctic (and Antarctic) near latitude 60°.

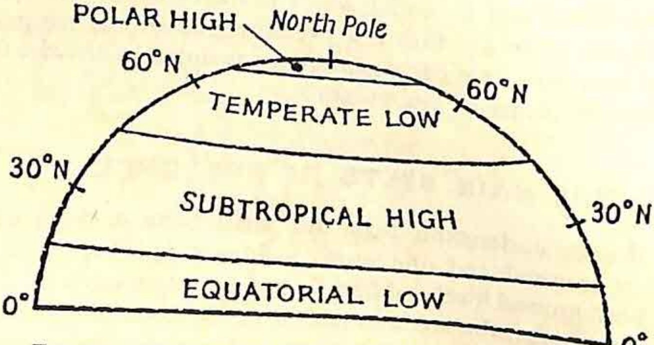


FIG. 14. *Main pressure belts in the Northern Hemisphere*

(2) prevailing high pressure near latitude 30°, especially over the oceans.

These two important zones are caused by the strong wind flow in the upper atmosphere at heights of 2 to 10 miles. This wind flow itself is generated by the main difference of heating between equator and pole – something which can be looked upon as the biggest convection current in the atmosphere. It must be realised that the wind and pressure pattern is constantly changing. Pressure belts are not continuous but are broken up into separate centres of high or low pressure.

As far as Great Britain is concerned, in winter there is usually an intense low pressure area to the north of the country around Iceland with high pressure to the south of the Azores, across Southern Europe and in Siberia.

In summer, the Icelandic low becomes less intense and the Azores high moves slightly nearer and intensifies.

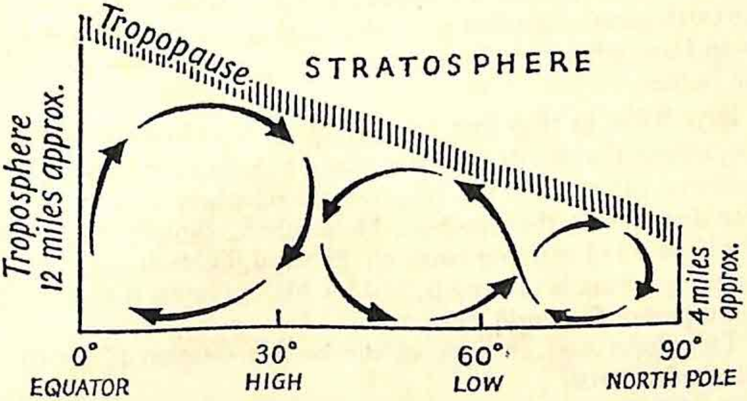


FIG. 15. *A simplified section of the winds in the Northern Hemisphere*

Fig. 15 shows a simplified section of the winds in the Northern Hemisphere. Until fresh discoveries are made about the circulation of the air in our atmosphere, the picture will not be complete.

5 Winds

1. 'FILLING UP' A DEPRESSION

In the last section we learned that the centre of an area of low pressure is known as a depression, and that the approach to a depression is a gradient of decreasing pressure. On a weather map this gradient is shown in isobars.

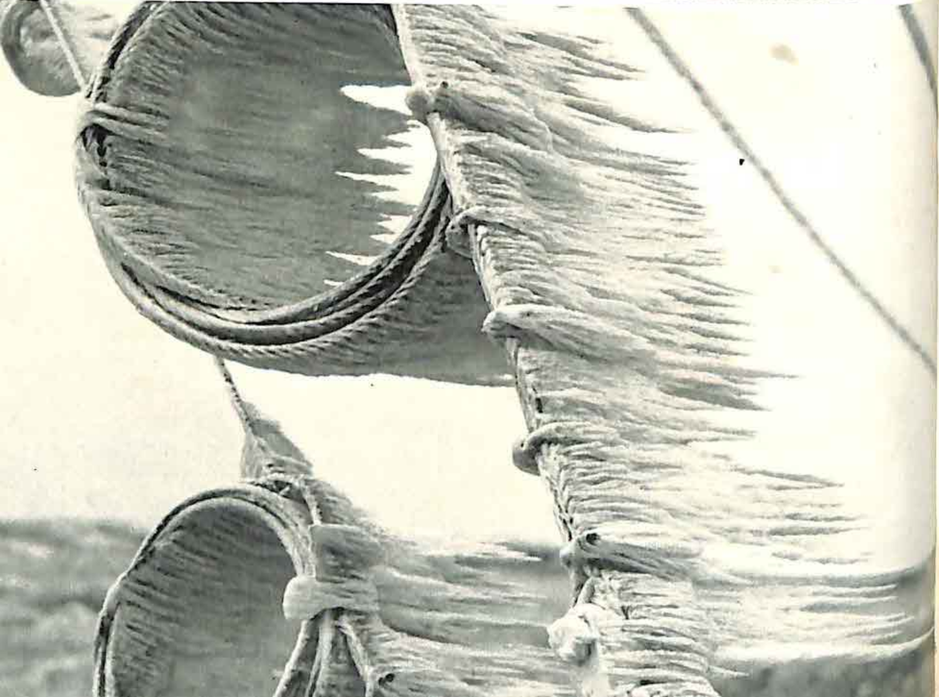
It might be expected that air would rush down the sides of the pressure 'bowl', causing an accumulation of air which would 'fill up' a depression. If the pressure gradient were the only force acting on the air, this is what would happen. In fact, the rotation of the earth causes the wind to be deflected to the right in the Northern Hemisphere, so that the winds blow more or less parallel to the isobars.

Buys Ballot in 1857 first put this observation into the form of a law, stating that winds circulate round a depression in a counter-clockwise direction in the Northern Hemisphere and in a clockwise direction in the Southern Hemisphere. Simply, this means that if we stand with our backs to the wind, i.e. facing downwind, the low pressure is to our left, and the high pressure is to our right in our part of the world. (Fig. 16).

This deflecting influence of the earth's rotation is known as *geostrophic* force.

In a depression, then, the wind blows round the sides of the 'bowl' in a counter-clockwise direction, moving only gradually towards the bottom of the slope, in much the same way as water drains from a wash basin. The speed of the wind is greatest where the gradient is steepest; the position of the greatest wind speed can

AN ANVIL OR THUNDERCLOUD



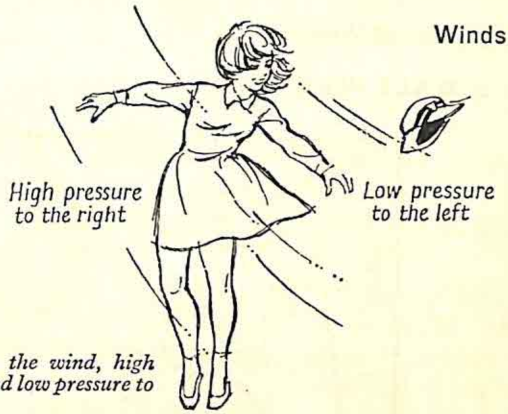

High pressure to the right
Low pressure to the left

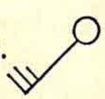
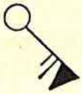
FIG. 16. *With back to the wind, high pressure is to the right and low pressure to the left.*

be plotted on a weather map by locating the isobars that are most closely placed.

The accumulating air in the centre of a depression is expelled by vertical currents which diverge strongly in the upper troposphere at heights of three to six miles.

In an anticyclone the wind blows in a clockwise direction, more or less along the isobars, and moving only gradually away from the centre of high pressure. The isobars are more widely spaced (i.e. the pressure gradient is weak) and the winds are much lighter.

The life of an anticyclone depends on the convergence of air at high altitudes above it. This convergence occurs at heights above three miles, and induces compression and descending air below it. This descending air is known as 'subsiding' air.

Wind direction and speed are shown on a weather map by a wind arrow drawn from the observation station in the direction from which the wind is blowing. The speed is shown by feathers and pennants entered on the side of the shaft of the wind arrow. A half feather represents 5 knots, a full feather 10 knots and a pennant 50 knots. e.g.  represents a south-west wind of 25 knots, and  a south-east wind of approx. 65 knots.

(*above*) HOAR FROST ON A WINDOW
(*below*) RIME ON THE STAYS OF A B.B.C. TELEVISION MAST

2. GALE WARNING

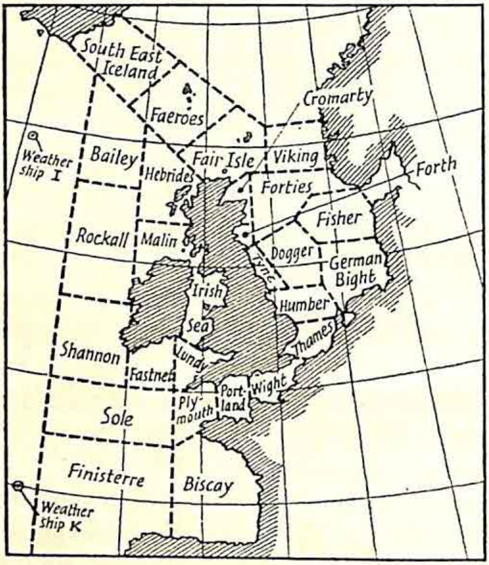


FIG. 17. *Sea Areas around the British Isles*

Compared with the storms and calms of America, we in Britain enjoy a gentle climate. We read of killer hurricanes roaring through American States, leaving acres of flood water, smashed homes and dazed survivors in their wake, and rejoice that we are spared such devastation and terror.

In September 1961, we were jolted from our complacency. Hurricane Betsy, having wrought havoc in America, was in the Atlantic and moving in the direction of the British Isles. She was now many days old and had lost the vigour and energy of youth, but her appetite for destruction had not been satisfied.

Increasing in size but less intense, Betsy was re-christened 'Low B' by the Meteorological Office. When she was still many hundreds of miles away from this country, south-westerly gale warnings were issued for sea areas Shannon, Fastnet, Lundy, Irish

Sea, Malin, Fair Isle, Viking, Forties, Cromarty, Forth, Tyne, Dogger and Fisher.

Gale Warning, 12th September 1961: 'In Hebrides, winds now expected to reach severe Gale Force 9 or Storm Force 10.'

Land areas in the west of England and Scotland were alerted: 'Storm Force 10 imminent.'

During 11th September, Betsy raced across the Atlantic in a north-easterly direction but, like so many depressions before her, as she approached Ireland she slowed down and moved towards the north-west of Scotland, trailing belts of rain and storm which were soon to sweep across the British Isles.

A gale summary issued at 0630 hours on 13th September showed that warnings were in operation in every one of the sea areas shown on Fig. 17. For days newspapers told tales of uprooted trees, roofs torn from houses, miraculous escapes, mountainous waves, floods and destruction.

Fig. 18 shows how Hurricane Betsy appeared on a weather map.

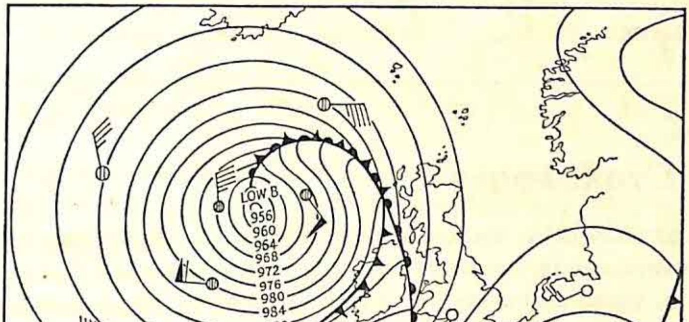

LOW B
956
960
964
968
972
976
980
984
988
992
996
1000
1004
1008
1012
WEATHER CHART AT 1200 HRS 12.9.61.
SHOWS OLD AMERICAN HURRICANE 'BETSY'
(LOW B) MOVING N.E. AND SLOWING DOWN

Fig. 18

MAN *v* NATURE

A typical hurricane is equivalent in energy to 10 Hiroshima-type atom bombs *every second.*

Could a nuclear explosion destroy a hurricane?

When a hurricane is forming, the effect of an explosion would be great but as yet there is no way of determining which of the many tropical disturbances will develop into hurricanes.

In any case it is by no means certain that the intense heat of an explosion might not intensify rather than suppress a hurricane in its formative stage.

The energy of an atomic explosion would be small compared to that of the storm in its mature stage and there is little likelihood of any lasting effect.

The effect of radioactive particles produced by an explosion would be a greater hazard to health than the storm.

3. TORNADOES

The tornado is the most violent of all storms. On average it lives less than an hour. Its track of damage varies from a few feet up to a mile in width and averages 13 miles in length. The longest track known is 300 miles.

The maximum winds around the dark funnel cloud are sometimes as much as 100 to 200 m.p.h. or more, although the tornado usually moves at a speed of 25 to 40 m.p.h.

In 1960 in the United States there were 618 tornadoes which resulted in the loss of 47 lives, whereas in the British Isles in a period of over 80 years there have been approximately 50 tornadoes which rarely caused loss of life.

The tornadoes which affected England on 21st May 1950, were exceptional. Born near Wendover in the Chiltern Hills at about four o'clock in the afternoon, they wandered in a generally north to north-east direction. Throughout the next two and a half hours, during which time it covered a distance of 65 miles into the Fen country near Ely, the main tornado continually lifted from the ground as it weakened, only to return after short spells, revived and more violent. Wendover, Aston Clinton, Linslade, Bedford South, Sutton and Ely lay in its path and suffered damage, excessive rain and hail, and, in many cases, flooding.

The total damage was estimated at £50,000. In Linslade alone more than 50 houses were unroofed and damage reached £25,000.

Sheets of corrugated iron were sucked into the funnel cloud to be returned to earth half a mile away. Solid objects were lifted up to 300 feet in the air before being scattered. The trunks of trees even up to 3 feet in diameter were twisted and torn off, while others were battered to the ground. More than 2 ins. of rain fell in many places and pieces of ice 2 ins. in diameter and a quarter of a pound in weight, consisting of many hailstones frozen together, were found.

4. WINDS OF THE NORTHERN HEMISPHERE

You may have noticed that the weather chart shown on television extends hundreds of miles into the Atlantic and that the weather usually moves to the British Isles from the west. It is difficult for the meteorologist to build up a complete picture of conditions over the ocean because of the few weather stations which transmit from this area.

From Aldergrove, an airfield in Northern Ireland, aircraft with trained observers take off every day on set flights over the Atlantic. They continually take readings at different heights and transmit information back to Britain where weather forecasters start their work of interpreting the readings. In addition, eight weather ships, maintained by various nations, are permanently stationed in the Atlantic. In all conditions, storm or calm, these ships remain at their set positions, except on rare occasions when engaged in air-sea rescue operations. The crews have the never-ending job of observing and reporting weather conditions, so that tomorrow's weather, carried on the westerly winds, can be forecast.

However, not all clouds come to Britain from the Atlantic, ready to drop their rain over land. It is not uncommon, especially on a summer afternoon, to find clear skies over the water and masses of cloud over the land. At the coast it is noticeable that on such afternoons there is often a breeze blowing in from the sea and the clouds move inland leaving the coast in sunshine. These facts should be remembered when you read of the surprising number of hours of sunshine enjoyed at some seaside resorts.

The following are the prevailing winds that we in the Northern Hemisphere experience at ground and sea level. These winds are related to the main belts of high and low pressure about which we read in Chapter 4, Section 3.

(1) A zone of variable but mostly north-easterly or easterly winds between latitude 60° and the north pole.
(2) The prevailing westerly winds of temperate latitudes between latitudes 30° and 60°.
(3) The Trade Winds, which blow towards the equator from the belt of highest pressure near latitude 30°.

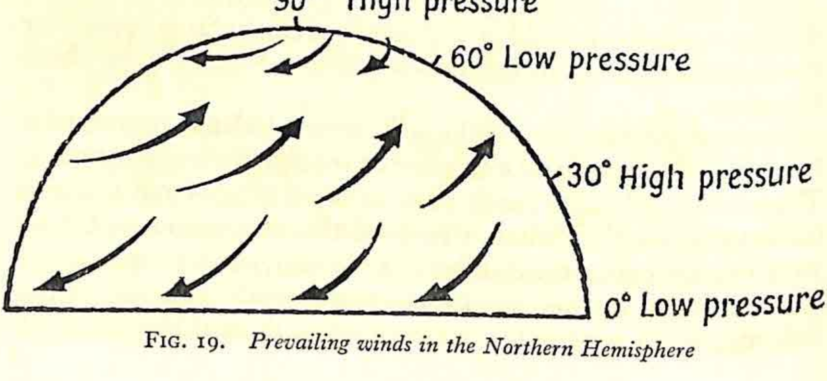


FIG. 19. *Prevailing winds in the Northern Hemisphere*

5. INSTRUMENTS

WEATHER COCK OR WIND VANE

This is used to show the direction of the wind. It consists of an arrow with a large tail or fin to catch the wind. Pivoted at its centre, it rotates so that the arrow points *into* the wind – that is, it points to the direction from which the wind is blowing and by which the wind is known, e.g. a south-west wind blows *from* the S.W. Beneath the arrow are fixed pointers showing the four cardinal points: N. S. E. and W.

WIND SOCK OR DROGUE

A familiar sight on airfields. It consists of a canvas sleeve, the larger end of which is kept open by a metal ring. This ring is attached to the top of a pole so that it can swing in any direction. When the wind is light or if there is no wind, the sock hangs limp. As the wind freshens, the sock is filled with air and points in the direction to which the wind is blowing. Aircraft, like birds, must take off and land 'into the wind'. Pilots can see the drogue as they circle the landing ground and so can position their craft properly.

ANEMOMETER

This instrument measures the strength of the wind. One common type of anemometer has three cups each fitted to the end of a metal arm, pivoted to rotate freely. The concave surfaces of the cups offer a greater resistance to the wind than the streamlined convex side, so the head bearing the cups rotates. The revolutions of the arms are geared to an indicator which shows the speed of the wind.

PRESSURE TUBE ANEMOMETER

At places where it is important to know the strength of the wind even in the brief gusts and lulls, this type of anemometer is used. The wind vane used in it consists of a hollow tube, facing into the wind. The pressure of the wind in this tube is communicated by pipe to a vessel in the Meteorological Office below the anemometer head. The pressure of the wind raises and lowers a float.

Generally, the wind is measured in knots, or in metres per second; in this country figures in 'miles per hour' are quoted. On page 119 comparative tables are shown. Here also you will find a copy of the Beaufort Scale of Wind Force, ranging from 0 to 12, that is from 'calm' to 'hurricane', originally drawn up in 1808 by Admiral Beaufort. It was intended for the use of sailors and referred to the canvas of a full-rigged frigate. Since that time, the Beaufort numbers have been adopted all over the world and their values standardised. By its use, a fair estimate can be made of the wind speed even when no instruments are available. One uses the movement of clouds, trees, smoke and birds.

Wind instruments are sited at a standard height of 33 feet (ten metres) above the ground so that their measurements are not unduly influenced by buildings and trees which cause eddies and turbulence in the air and rapid fluctuations in the wind strength. These sudden bursts are known as gusts.

Descriptions of particular winds or wind circulations, such as cyclone, 'chinook', mistral, etc. can be found in the Glossary of Meteorological Terms.

WB 47's REPORTING

WB 47's of the U.S. Weather Service fly up to 40,000 feet. Instruments carried automatically take and transmit weather information at 1,000 characters a minute, to ground receiving stations.

The WB 47 does *not*, like its predecessor, the WB 50, fly into hurricanes, penetrating to the central eye. Radar in the aircraft provides an accurate picture of the storm structure.

6 Airmasses and Fronts

1. AIRMASSES

In Britain we can have warm, moist conditions over the country one day and bitterly cold, dry conditions the next. This may have nothing to do with the amount of sunshine during those days, nor does it mean that the air has changed its temperature and humidity overnight. It is the air itself that has been changed. The warm air has been pushed away and cold air has taken its place.

All over the world at any given moment of time this struggle and interchange is taking place between great masses of air, some warm and some cold. Where unlike masses of air meet at *fronts*, the most violent of our weather is born.

An *airmass* signifies an area of many thousands of square miles covered by air which, at the same height, has roughly the same pressure, temperature and humidity throughout.

Since it has achieved its condition by contact with the earth, this means that air must stagnate in or travel over one extensive region of the earth for several days before a mass of it can come into balance or harmony (equilibrium) with the characteristics of the earth's surface in that region. Throughout the world there are comparatively few places with a surface sufficiently large and uniform for this to happen.

The main source regions for airmasses are found in the slow-moving anticyclones around the poles and in the sub-tropical high pressure belts. Airmasses, then, are either polar (P) or tropical (T) in origin.

Extensive sea or land surfaces exert a fairly uniform, modifying influence on air streams passing over them. This means that a moving airmass is modified, especially in its lowest layers, by its *track* or *journey* – that is, the surface of the earth over which it travels. A track over sea is known as *maritime* (m), a track over land, *continental* (c). When polar air moves south over the sea, it is warmed and moistened from below and becomes unstable; frequent heavy showers can be expected. When sub-tropical air moves north it is cooled from below and becomes stable; there will be little vertical movement of air and clouds will form in shallow layers.

2. TYPES OF AIRMASSES

Meteorologists classify an air stream according to its track (m or c) and its source (P or T). Four main types of airmass visit Great Britain: mP (maritime polar), cP (continental polar), mT (maritime tropical) and cT (continental tropical).

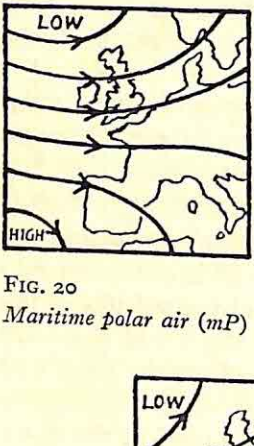


FIG. 20
Maritime polar air (mP)

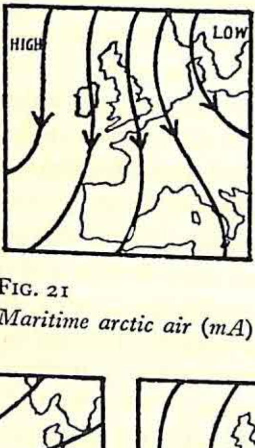


FIG. 21
Maritime arctic air (mA)

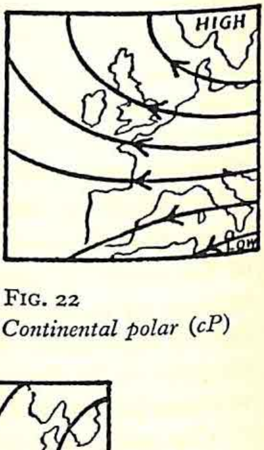


FIG. 22
Continental polar (cP)

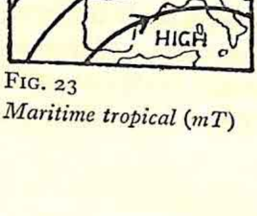


FIG. 23
Maritime tropical (mT)

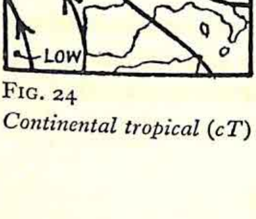


FIG. 24
Continental tropical (cT)

MARITIME POLAR (mP)

Convection clouds build up over the Atlantic. Over the land the air is relatively cold and still fairly dry – that is, water content (or relative humidity) is fairly low, even after the air has crossed from Canada or Greenland. Showers of rain or snow are frequent over the exposed west and north-west coasts. In winter, the clouds tend to disperse inland to give clear skies; at night, severe air frosts are common. In summer, the heat of the land causes clouds to build up and showers are frequent, especially in the east of Britain. When polar air reaches Britain from the north (see Fig. 21) it is sometimes called *maritime arctic* (mA). After a short and direct journey from its source region, it is very cold and unstable. Snow showers are heavy and frequent over the exposed north and north-east coasts and over high ground inland. Air frost is severe at night and often persists all day.

CONTINENTAL POLAR (cP)

Easterly winds bring polar air from Siberia. Although very dry and cold, the air has been moistened in its lowest layers while passing over the North Sea and snow showers are frequent in the east and north-east of England and in eastern Scotland. In winter, day and night temperatures are usually below freezing level, especially in the south-east of England where the sea crossing is shorter, and there snow showers are much less frequent. In summer, the cool air is often cloud-free over Britain, though the east coast districts are liable to experience sea fog.

MARITIME TROPICAL (mT)

In winter, south-west winds bring warm moist air over Britain. The stable airmass often causes a layer of low cloud or stratus, and drizzle is likely. The cloud may persist night and day, except in the east, where breaks are possible, caused by the effect of hills over which the air passes, and the heating of the land and evaporation of the cloud.

CONTINENTAL TROPICAL (cT)

South and south-east winds in summer sometimes bring hot air from the North African desert; this air formation is usually responsible for our summer heatwaves. Generally the air is too dry for cloud formation, though sometimes sufficient moisture is picked up over the Mediterranean Sea for clouds to form inland over France. Thunderstorms are possible because of the heat of the land, and these storms often drift over southern England during late afternoon and early evening in summer.

3. FRONTS

We have already referred to the constant conflict taking place between neighbouring unlike airmasses. As far as Britain is concerned, the polar front where unlike forces meet lies mainly in the temperate zone, but sways back and forth as the conflict rages.

Over most of the temperate zone this polar front moves some degrees of latitude north and south following the seasonal movement of the sun. Over Britain and Europe the seasonal movement is very slight and irregular; the seasonal changes of frontal activity are more marked in the Mediterranean.

In winter, Britain is a favourite battle-ground for unlike fronts. One day we are in a cold air stream, the next in a warm one, and the passage of each front may be marked by a belt of rain, a change of wind, humidity and temperature. In our finest summers, the fronts often pass to the north of Britain, which is left in relatively warmer air.

The polar front marks the point where the polar air from the north meets tropical air from the south; in fact, the two air streams may flow peaceably side by side. The frontal surface is rarely vertical; the colder denser air hugs the ground to form a wedgelike shape beneath the warmer lighter air.

4. TYPES OF FRONTS

When warm air advances and cold air is pushed back on the surface of the earth, this is known as a *warm front*. Conversely, when cold air replaces warm air at a given point, this is known as a *cold front*. The symbols denoting the kind of front are drawn on weather maps along the leading edge of the front so that they show not only what kind of front it is, but also which way it is going. When the front stays more or less in the same place, it is known as *quasi-stationary*, and the symbols are drawn on both sides.

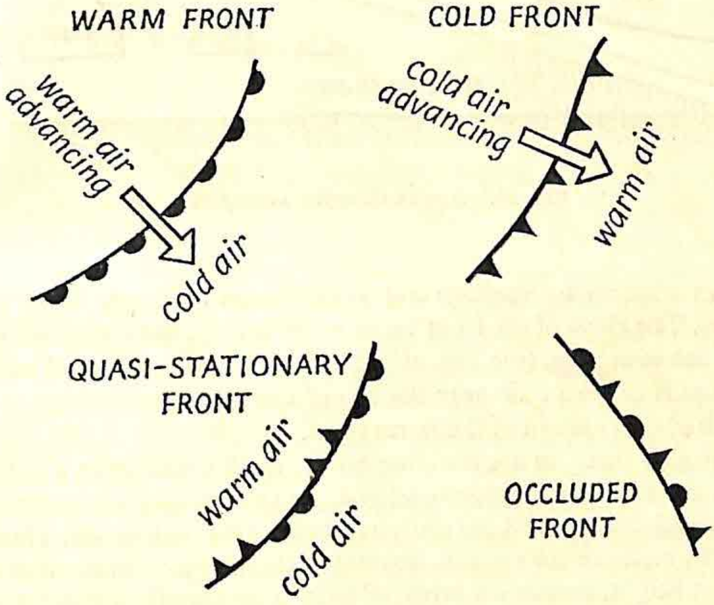


FIG. 25

A WARM FRONT

When warm air advances against the wedge of cold air, it leaves the ground and climbs a gentle slope over the cold air. The slow ascent

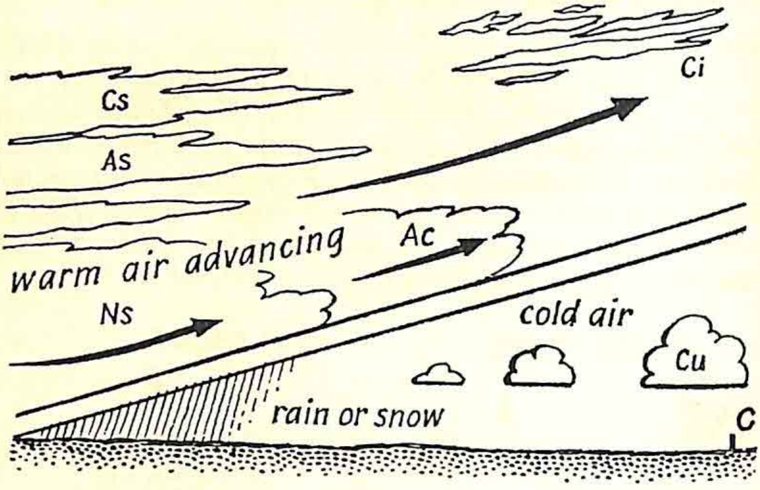


FIG. 26. *Section through a warm front*

causes expansion, cooling and condensation. Clouds form in layers. The slope of the front varies considerably, but a gradient of 1 in 200 is average (see Fig. 26). The high clouds associated with the uplift of warm air near the top of the slope are seen several hundred miles ahead of the warm front.

Imagine that you are standing on the earth's surface at a point C in the figure. High overhead you see thin streaks and tufts of cloud which are pulled out into streamers by the high winds. These clouds, made of ice crystals because of the very low temperatures at that height, are known as mares' tails. If they tend to thicken and spread over the sky, it is a fairly reliable indication that a warm front is approaching. If the front at the earth's surface moves at a speed of about 25 to 30 m.p.h., it will take about 24 hours to cover say 500 miles. Thus you have a day's notice of the warm front's arrival.

When the thin transparent ice cloud covers the whole sky, around the veiled sun or moon may be seen haloes at 22° (the angle of the sun or moon to the observer and back to the halo). The high clouds gradually thicken into a fairly high uniform grey cloud-sheet which eventually obliterates the sun. Any convection clouds already in the sky become smaller as the ceiling of warm air above them comes lower. The barometer drops steadily, the wind backs and the air becomes more moist. Rain or snow, gentle at first, falls from the layer of medium height clouds and gradually increases as the cloud base lowers. As the front passes through point C, the wind veers, the fall of atmospheric pressure is checked, and the relative humidity and the temperature rise. The rain (or snow) stops, but the sky remains overcast. Drizzle and even fog may follow in the warmer air.

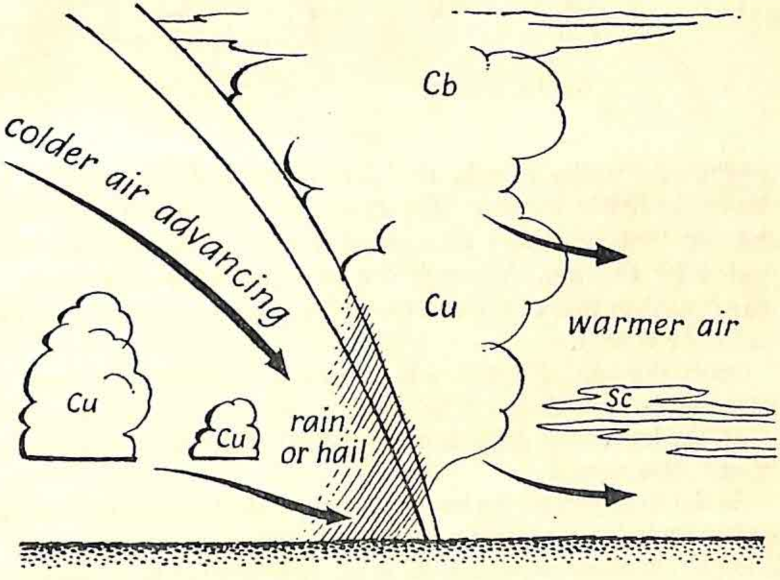


FIG. 27. *Section through a typical cold front*

A COLD FRONT

If an advancing warm front stops and returns the way it came, it returns as a cold front. You must not think, however, that the weather conditions in a cold front are always the reverse of those in a warm front. A so-called typical cold front is very different. The main difference is that the frontal surface between the two airmasses becomes much steeper, the cold air in contact with the earth being held back by friction.

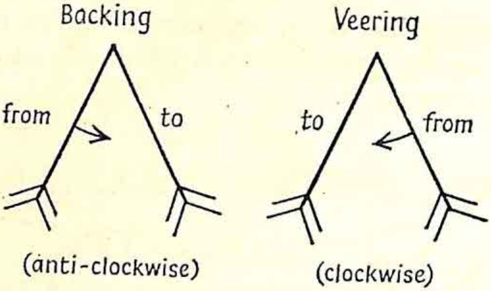


FIG. 28

When the wedge of cold air drives forward, the warmer air is thrust vigorously upwards. The clouds formed are tall and deep, and usually bring heavy showers of rain and hail, often accompanied by thunder. Although the rain belt of a cold front is narrower than that of a warm front, it is correspondingly heavier and more violent.

Often the line of tall clouds of an approaching cold front is obscured by low clouds. The approaching front can be detected when the barometer drops rapidly and the wind backs as the cold front comes nearer.

As the front passes, the heavy rain stops, the barometer kicks up and the winds veer sharply. A typical figure for this veer is 30°, though individual parts may show either smaller or larger veers of wind. At first the sky is clear behind the retreating line of tall clouds, but within a short time convection clouds begin to build up in the cold unstable air.

(*above*) LOW-LYING FOG
(*below*) MEDIUM HEIGHT CLOUDS OVER SOUTHERN FLORIDA

7 Depressions and Anticyclones

1. GROWTH OF A DEPRESSION

In chapter 5, we saw that in a depression:

1. The atmospheric pressure is low at its centre;
2. The winds circulate around its centre in a counter-clockwise direction in the northern hemisphere;
3. The air converges at surface level;
4. There is divergence of air at heights above the centre of low pressure as air is lifted upwards and expelled.

We have also seen how the heat of the sun's rays over a land mass can cause large up-currents of air over the land with a drop in air pressure at the surface. This type of depression, known as a *thermal depression*, is a temporary disturbance only, and disappears as the earth cools. Similarly a warm sea with unstable polar air above can produce a *polar low*.

High mountains, by forcing air to rise in order to pass over them, reduce the air pressure on the lee (sheltered) side. If the mountains are sufficiently high, a 'low' known as an *orographic depression* will develop.

However, the depressions which have by far the greatest effect on weather in Britain are those which form in the Atlantic on the polar front. A theory put forward in 1919 by the Norwegian meteorologists V. and J. Bjerknes still forms the basis of modern thinking on this subject, in spite of the considerable research since undertaken.

Imagine the polar front lying in an east-west direction, with

(*above*) FAIR WEATHER CUMULUS

(*below*) TOWERING CUMULUS

polar air to the north and tropical air to the south, with both air streams flowing towards the east. As the frontal surface is rarely vertical, the warm air is flowing across a gentle slope of cold air.

Warm air is less dense than cold air, and just as air flowing over water causes waves, so warm air flowing over cold air produces waves in the front separating them. The waves vary in size and frequency according to the speed of the air flow.

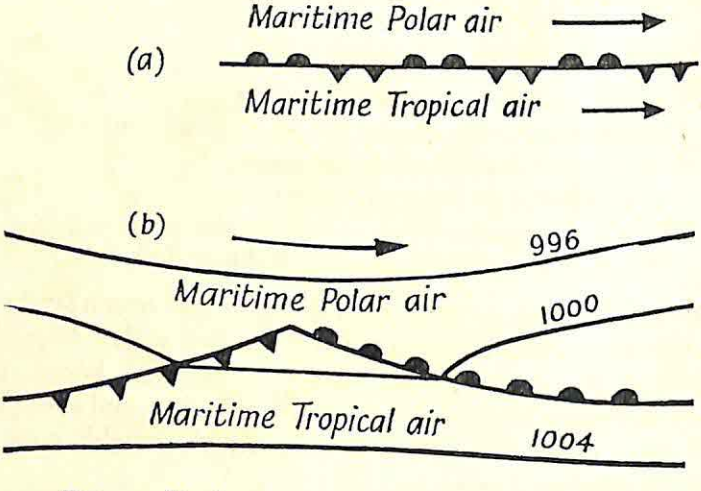


FIG. 29. *Development of a frontal wave in the Polar Front*

These waves, like small spearhead advances of warm air into cold air, are carried east at the same speed as the main mass of warm air. Many waves do not develop beyond this stage and have little effect on the weather, beyond reducing the air pressure slightly. Other waves are bigger. Not only does warm air advance further into the region occupied by cold air, but it is also pushed higher and may become unstable when there is enough condensation of moisture going on. Once the stability of the warm air has been disturbed, a depression develops very rapidly. But many wave depressions develop without reaching this extreme point. As warm air pushes into and up over cold air, the pressure drops and the cold air whirls round in an effort to contain the warm air. A counter-clockwise wind circulation is produced and a frontal depression with a sector of warm air is born.

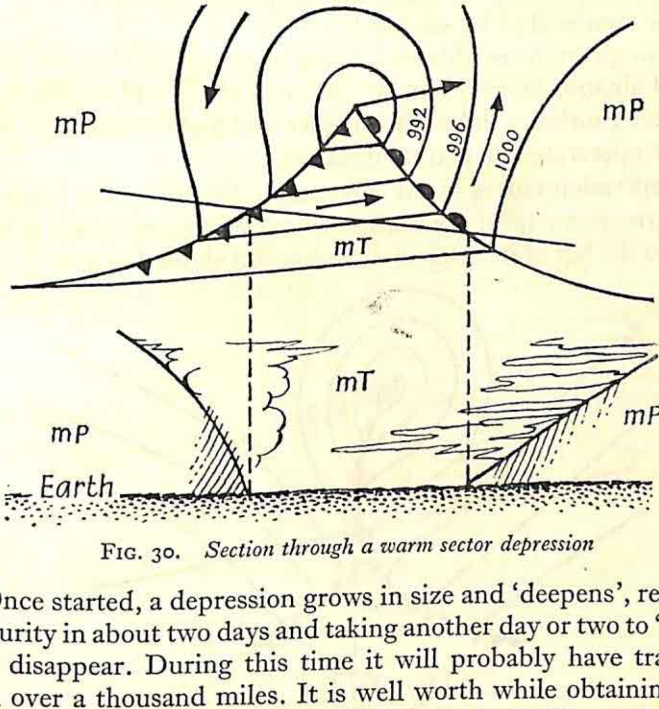


FIG. 30. *Section through a warm sector depression*

Once started, a depression grows in size and 'deepens', reaching maturity in about two days and taking another day or two to 'fill up' and disappear. During this time it will probably have travelled well over a thousand miles. It is well worth while obtaining successive weather charts from the Meteorological Office and studying the development of a depression, noting the air pressure, the speed and direction of its centre, and the movement of fronts. It will be noticed that most depressions, born hundreds of miles away in the Atlantic, are a day or two old on reaching Britain and some are already becoming less intense.

2. MOVEMENT

A cold front always moves more quickly than a warm front, in which the advancing air tends to climb rather than to advance. The warm sector becomes narrower as the cold front gradually overtakes the warm front. This means that the wedge of cold air behind a cold front joins up with the cold air in advance of the warm front, pushing the warm air completely off the ground. The front is then said to be *occluded*.

Although on the earth's surface the properties of the two masses of cold air may be very similar, rain and cloud will persist as the warm air continues to be lifted higher and higher, causing expansion, temperature fall, and condensation.

A depression moves in the direction indicated by the isobars in the warm sector until the occlusion process begins, when it turns more to the left of its original direction and slows down.

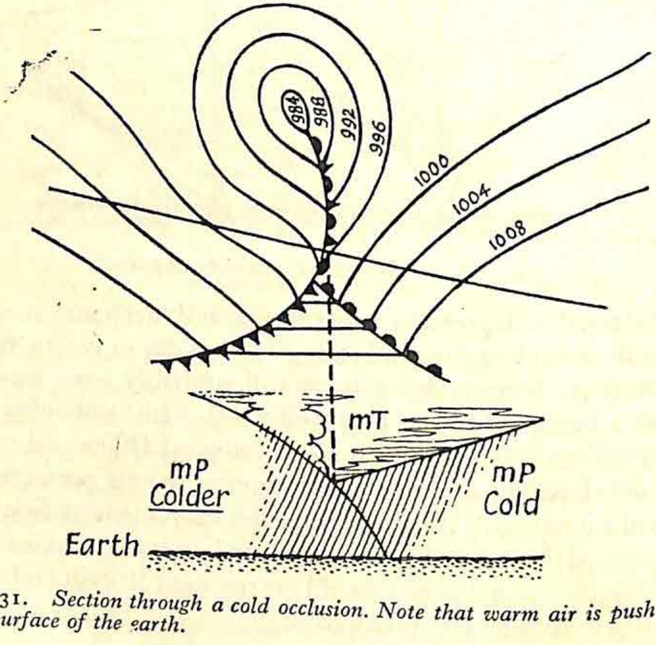


FIG. 31. *Section through a cold occlusion. Note that warm air is pushed off the surface of the earth.*

An observer on the ground sometimes finds it difficult to realise that, although there is, say, an easterly or south-easterly wind blowing at the time, better weather will eventually appear in the west. The easterly or south-easterly wind is part of the counter-clockwise circulation of wind around a depression; what must be appreciated is that the depression itself is moving to the east. Think of the depression as a spinning top, where the movement of the top across a floor is entirely separate from the revolutions of the top as it turns.

Depressions seem to develop in families of from two to five. As one depression becomes partly occluded and a cold front trails

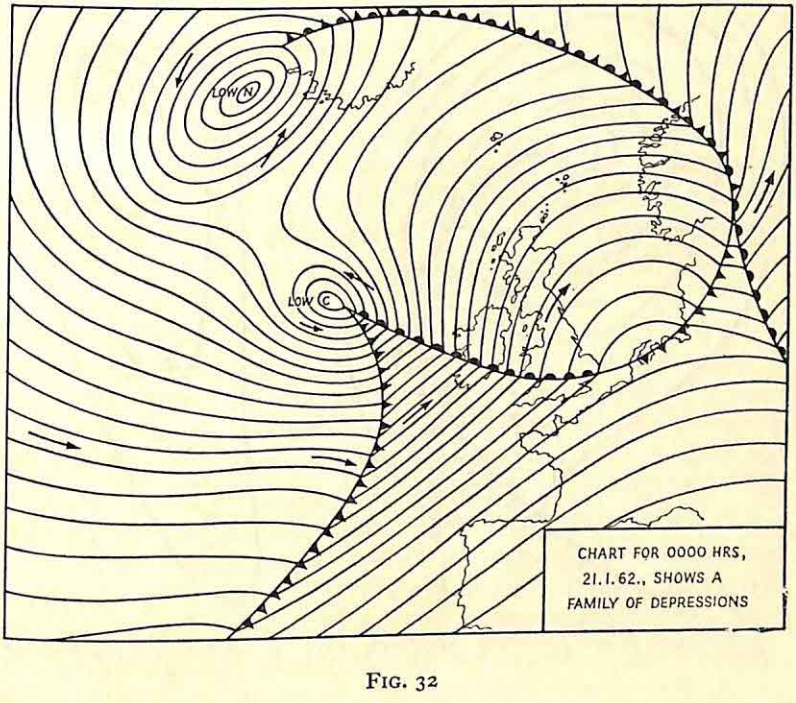
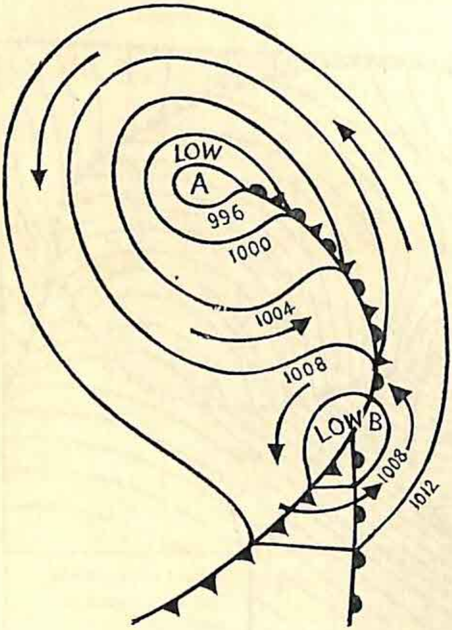


FIG. 32

back over the Atlantic, so another wave depression develops. This 'low' follows hard on the heels of its predecessor, but sometimes tends to come further south.

The cold front disappears when the cold air has spread so far south over even wider regions of the globe that it becomes shallow, easily heated up throughout its depth and converted into tropical air. Meanwhile, a new front appears to the north-west, between two masses fresh from their source regions and the battle begins all over again.

A depression is sometimes given a longer and more vigorous life by the formation of a separate centre of low pressure within its



G. 33. *Low B is a secondary depression.*

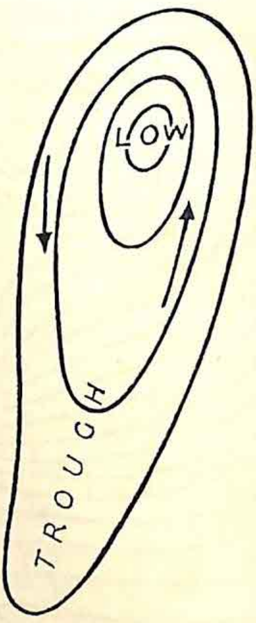


FIG. 34. *A trough of low pressure*

circulation. Starting with a variation in the air pressure, usually on the southern side, the *secondary depression* develops its own circulation so that it appears as a long kidney-shaped depression with two centres, the primary and the secondary centre (see Fig. 33). These move round one another in a counter-clockwise direction like a two-chair roundabout, while the whole system moves on its way independently.

The secondary depression often becomes more vigorous than the parent or primary depression and sometimes absorbs it into its own circulation. *A trough of low pressure* is shown on a weather map by extending the isobars away from a centre of low pressure in a long, sometimes even a finger-shaped, valley. A trough brings weather rather like that of a cold front.

3. ANTICYCLONES

An anticyclone is a region of high pressure around which the winds blow in a clockwise direction in the northern hemisphere. It is usually much bigger than a depression and is shown on a weather map with far fewer and more widely spaced isobars, so that the pressure gradient is gradual and the winds are light, especially near the central area (see Fig. 13). A 'high' is usually much slower moving and more persistent than a 'low'.

In a depression, air converges at ground level and diverges aloft; in contrast, in anticyclones, air converges aloft and diverges at ground level. In a depression, air is lifted and expands, with consequent falling temperature and condensation; in an anticyclone, air subsides, is compressed and has its temperature raised so that very low relative humidities may occur in the subsiding air. High pressure usually means dry, but not necessarily clear, weather.

On winter days, bubbles of relatively warm air leave the ground and condensation takes place. The clouds are unable to rise through the warmer air above and are flattened out and spread into a layer of clouds which give dry but gloomy conditions – hence the name given to these conditions: *anticyclonic gloom*.

At night this cloud often disperses so that, with clear skies and little wind, fog develops quickly. We sometimes come under the influence of the high pressure area which is almost permanently positioned near the Azores, especially in summer, and generally it can be relied upon to bring weather known as *fine* (with no cloud at all) or *fair* (with a few small clouds).

A ridge of high pressure corresponds to a ridge running out from the side of a mountain. On the weather map this ridge is shown with the isobars extending outwards from the centre of the 'high' in the same way as the contours of a ridge.

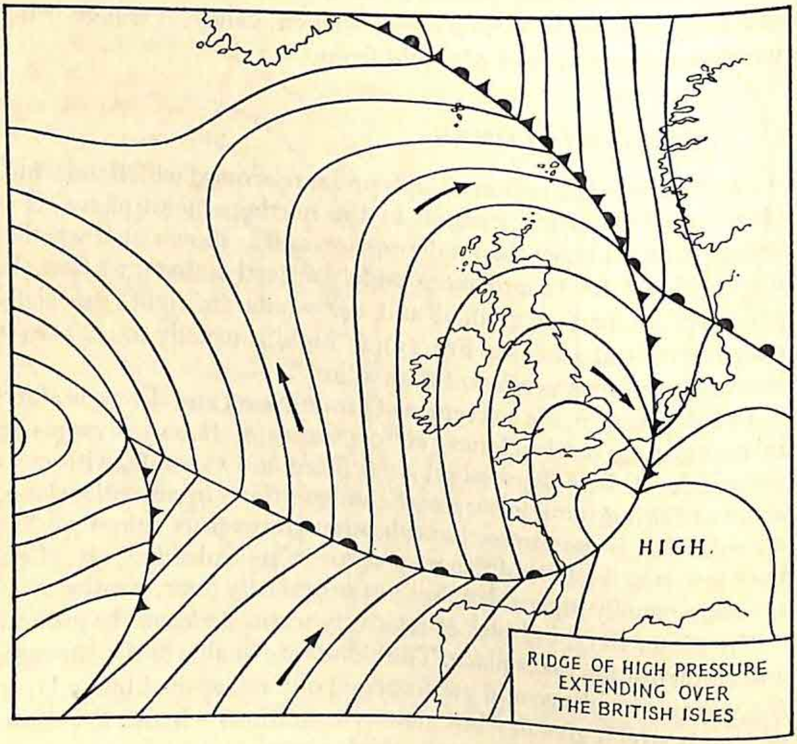


FIG. 35

Fig. 35 shows a ridge from the Azores 'high' extending over the British Isles. The passage of depressions across the country is often punctuated by a ridge of high pressure which brings some pleasant hours of sunshine between the disturbances. It is quite common for a ridge of high pressure to develop its own circulation and change into an anticyclone, or to join up with and be absorbed by another anticyclone.

A cold anticyclone, similar to a thermal low, is created over large land masses. In winter, the ground in places like Siberia becomes very cold. The air in contact with it is progressively cooled and contracts so that high pressure is built up. Although very high pressures are recorded, these anticyclones have no great depth compared to the warm anticyclones of the sub-tropical regions. They are difficult to dislodge from the main cold regions where they are formed, but in fringe regions, as when they are over Britain or Norway, they are more easily broken down.

8 Clouds

1. WHAT CLOUDS ARE MADE OF

Clouds consist of minute, floating droplets of water, or small ice particles – according to the temperature. The droplets are so small that it would take about a million of them to make one raindrop. However, the amount of water suspended in the air in cloud is considerable. The weight of water in one isolated, average-sized cloud exceeds tens of thousands of tons.

The very high clouds consist of ice particles (snow) and the lower ones of water droplets.

We all realise that in any air stream, polar or tropical, the higher we climb into the air the colder it becomes. Some air streams are so cold that during the day in winter the temperature even on the ground is well below 0° C. – freezing point – and the ice on lakes and rivers is thick enough to allow skating. Generally, however, the freezing level is well above the ground and the warmer the air-stream the higher it is. On average, over Britain it is between 3–5,000 feet in winter and 9–12,000 feet in summer.

It would be reasonable to expect any cloud reaching above freezing level to consist entirely of ice crystals. In fact, research has shown that only one cloud particle in a million is frozen at −10° C. and that the temperature has to fall to −40° C. before all the condensation takes place as ice crystals.

The one important factor which causes water at the edge of a pool to begin to freeze at 0° C. is the presence of impurities in the water. The distilled water in the hygrometer, like cloud droplets, may remain liquid at temperatures far below the freezing point. It is then said to be *supercooled*.

It is important to note that if supercooled cloud droplets are disturbed or touch an ice crystal, they freeze immediately. Pilots of aircraft are well aware of the risk of icing when flying in clouds of supercooled droplets.

2. FORMATION OF CLOUDS

We have already seen how cloud is formed when air is chilled below its dew point (see page 32).

This cooling or chilling of the air can be brought about in two main ways:

(1) By coming into contact with a surface of the earth which is cooler than the dew point of the air (fog, sea fog, and stratus are produced by this method), and

(2) By expansion. When air rises it expands because the atmospheric pressure is reduced as height increases. As the air expands its temperature drops. These changes in the temperature of a gas which take place without any heat entering or leaving the gas are known as *adiabatic* changes. All clouds which form in the air away from the ground are produced in this way. They include (*a*) frontal clouds, (*b*) convection clouds and (*c*) orographic clouds, i.e. clouds formed over high ground.

A. FRONTAL CLOUD

In a warm front the slowly rising air produces layers or sheets of cloud of various types. The clouds on a steeper cold front have a more vertical growth.

B. CONVECTION CLOUDS

We have already seen how the surface of the earth is warmed by the sun's rays (insolation). Consequently, the air in contact with the earth is warmed and rises. As it rises it expands because of the reduced atmospheric pressure and the expansion causes the air's temperature to drop. If the temperature drops below its dew point, cloud will form. This cloud, which in appearance is often likened to pieces of cotton wool, and is called cumulus, forms in isolated, separated places.

No doubt you have often wondered why cloud does not form in a continuous layer. The main reason is that the air is not evenly heated. Just as the air over a roadway or over a car is warmed more than that over a grassy surface, so the air over a city is far warmer than that over the countryside. You have often noticed the warm air rising from the hot surface of a road in summer. The warm air over a city or any other large source of heat similarly rises through the cooler surrounding air like a giant bubble. It continues to rise as long as it remains warmer. It is in these convection currents, known as thermals, that clouds will form if the thermal has enough energy to reach beyond the condensation level.

Glider pilots, like many birds, depend on finding thermals which are vigorous enough to lift them high into the air against the pull of gravity. However, for reasons of safety, glider pilots are not permitted to fly over cities.

In the wake of a thermal the air is warmer so that succeeding thermals, following in the same track, are able to reach greater heights.

A large cumulus cloud, travelling across the country with the wind will be fed by many thermals from different heat sources.

Note that these clouds disperse, as insolation decreases.

C. OROGRAPHIC CLOUDS

In Fig. 36a the air is forced to rise over the mountain and has its temperature lowered below its dew point so that cloud has formed. As the airmass is stable, the cloud has not grown upward to any large extent and there is no rain. The cloud, known as a banner cloud, is constantly changing with fresh condensation taking place at A and continuous evaporation taking place at B.

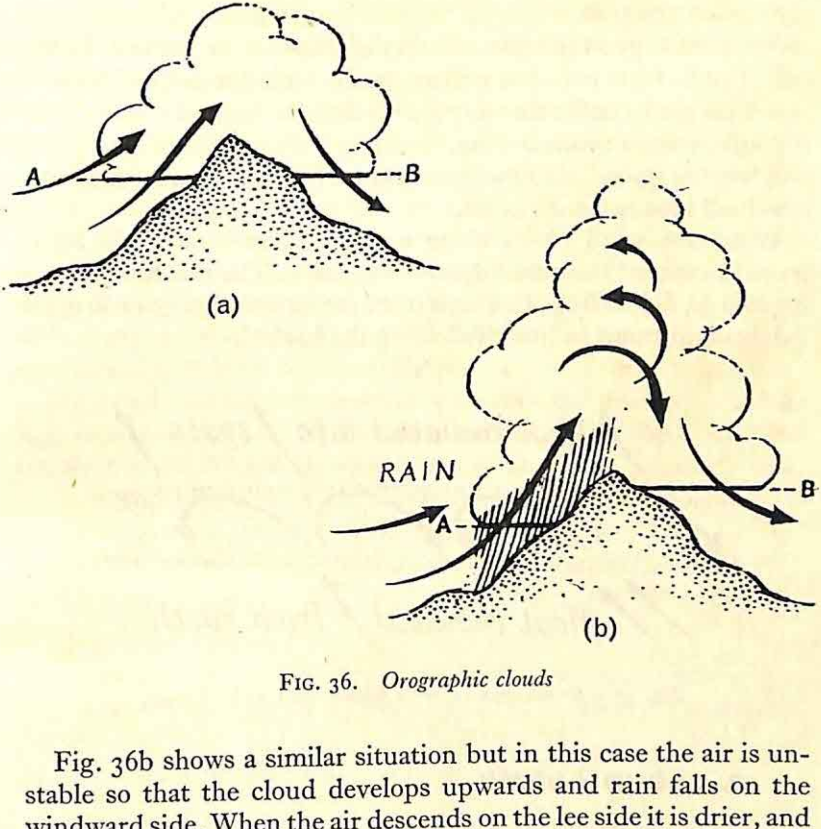


FIG. 36. *Orographic clouds*

Fig. 36b shows a similar situation but in this case the air is unstable so that the cloud develops upwards and rain falls on the windward side. When the air descends on the lee side it is drier, and therefore the level where evaporation takes place is higher than the condensation level on the windward side.

There is a danger of thinking that this air has got rid of all its moisture in the same way as a bomber releases its load. If there is another mountain, say, 50 miles away, this same air will again cause cloud and rain if the air is forced high enough. In fact, most of the water vapour in any airstream can be made to condense if the air is chilled sufficiently. An additional factor to be borne in mind is that the air picks up moisture again from all available sources on the way.

Air, even at great heights, echoes the shape of the ground. *Lenticular* clouds form over but well above the high ground, in layers of air which are so moist that any ascent such as occurs in waves over the hills, causes condensation.

A '*cap*' or '*pileus*' cloud will sometimes form above a large cumulus cloud for the same reason.

When the wind blows along a range of mountains the air is forced to ascend over considerable distances. The resulting cumulus clouds, fed by fresh thermals from the mountains, grow to great heights and travel in lines 'following the leader'.

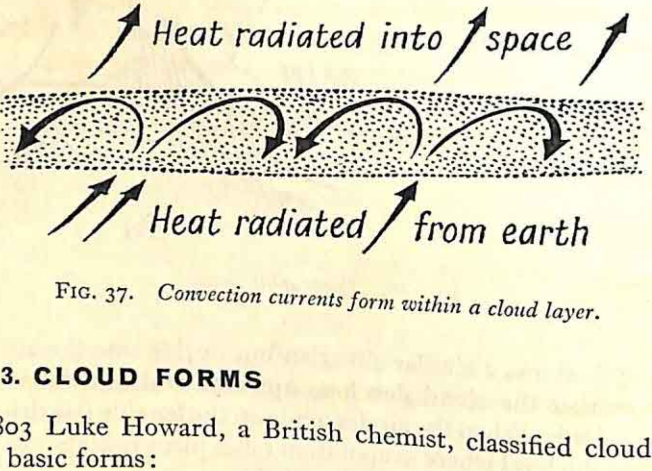


FIG. 37. *Convection currents form within a cloud layer.*

3. CLOUD FORMS

In 1803 Luke Howard, a British chemist, classified clouds into three basic forms:

1. CIRRUS (meaning a hair) consisting of ice crystals and having a characteristic thin, streaky and feathery appearance.
2. STRATUS (meaning a layer) moving across the sky as if a giant sheet were being pulled from one horizon to the other.
3. CUMULUS (meaning a heap) referring to the lumpy, flat-bottomed clouds with cauliflower tops.

The shape and form of clouds reflect conditions in the air. They are constantly changing. Two ways in which the layer or stratus clouds frequently change into a cumulus form of *rippled cloud* illustrates this point.

When the sky is clear above a cloud sheet, the top of the cloud cools as heat is radiated into space. Meanwhile the base of the cloud receives heat radiated from the earth. Shallow convection takes place within the cloud layer which splits up into cells, the cloud thickening with the up-currents of air and evaporating with the down-currents. The size of the ripples depends on the thickness of the layer. They may also be formed as ripples; this is caused by differences of wind speed above and below the cloud layer. The size then depends on the wind shear.

We have listed the three basic cloud forms, but modern meteorology demands more detail. The International Cloud Atlas contains ten main types with many varieties of each.

CIRRUS (Ci)

High cloud. A delicate cloud made of ice crystals. At height, the wind usually becomes stronger and changes direction. These strong winds draw out the ice crystals into curling, diffuse-edged trails which have a fibrous hairlike appearance. They are popularly called mares' tails and often are the first visible signs of the approach of a warm front still 500 miles or more to windward.

CIRROSTRATUS (Cs)

High cloud. As the name implies, this is a layer of cirrus, with a thin, transparent, veiled appearance. In an approaching warm front, the thin end of the wedge of warm air can first be seen by the increasing amount of cirrus at 30–35,000 feet high. As the cirrus thickens, bright haloes may be seen around the blurred outlines of the sun or moon.

CIRROCUMULUS (Cc)

High cloud. A cirrus layer with tiny white delicate masses or ripples. It is sometimes called a 'mackerel sky'.

ALTOSTRATUS (As)

Cloud of medium heights, 8,000–20,000 feet or so. As cirrostratus deepens it changes from a white veil to a dull greyish layer. Haloes are obliterated and the gleam of the sun or moon is seen but vaguely if at all. It consists of a deep layer of ice crystals and waterdrops from which rain or snow falls in the steady advance of a warm front.

ALTOCUMULUS (Ac)

Another cloud at medium heights. A layer or patch of white or grey cloud with rolls or billows which may or may not be joined. These generally have shadow and are composed of supercooled droplets of water.

NIMBOSTRATUS (Ns)

Low cloud, i.e. cloud with base below 8,000 feet. As altostratus thickens it becomes a darker grey and produces rain or snow; the cloud lowers with turbulent clouds forming in the moistened air beneath. The cloud may be solid from the base of the nimbostratus (about 600 feet) to the cirrostratus at about 30,000 feet. Rain will then be continuous without any brighter patches in the clouds. A warm front cloud mass is often built up in a series of layers with clear air between them.

STRATOCUMULUS (Sc)

Also a low cloud. A layer or patch of grey-white cloud formed in

(*above*) CIRRUS—MARES' TAILS
(*middle*) CIRROCUMULUS
(*below*) CIRROSTRATUS WITH ALTOCU

rounded masses or in rolls. They can be seen in lines or in waves set either across or in line with the wind, or both ways.

STRATUS (St)

Also a low cloud, having a uniformly grey and formless appearance. It may give drizzle.

CUMULUS

(*a*) *Fair weather* – low cloud, i.e. cloud with base below 8,000 feet. The photograph facing page 65 shows cumulus in the sky on a typical sunny afternoon. It is white droplet cloud with a fairly flat horizontal base. When the air is dry and stable, small clouds may form in the thermals but the tops are clean cut and soon tend to flatten. As the day continues, the temperature rises and the bases of the cumulus clouds are pushed higher until the clouds completely evaporate.

(*b*) *Towering cumulus* – low cloud, i.e. its base is low – below 8,000 feet. The photograph facing page 65 shows cumulus clouds which have grown taller as the ground temperature has risen. The tops are domed and sharp, consisting of a number of towers, each pushing up into the deep blue sky in a forceful boiling action. The underside of the cloud grows darker and threatening as the cloud pushes upwards. The growth of this cloud merits close attention. As a new tower breaks through into the clear, cold air above, it stands for some minutes unchallenged above its colleagues. But the up-current shoots beyond the level of equilibrium before it is decelerated and halted. After reaching its maximum height the cloud tower tends to sink somewhat. It also cools gradually by radiating its heat to space and mixing with the surrounding air. And its water content tends to fall out. Should the air undergo further surface heating, the tower's place is soon taken by another which reaches even greater heights.

(*above*) ALTOCUMULUS
(*middle*) STRATOCUMULUS
(*below*) STATIONARY WAVE CLOUDS OVER MOUNTAINS

Much of the upper part of the cloud will consist of supercooled droplets and ice crystals. As the larger ice particles fall, water is distilled on them from the droplets until most of the cloud above freezing level consists of ice crystals.

CUMULONIMBUS

As a towering cumulus is fed with more thermals, fresh towers add to the mass of ice crystals which fan outwards from the cloud top in feathery wisps. As the vertical currents in which the cloud has been formed level off and fan out at the top, the familiar anvil shape of the cloud top appears. The anvil consists of ice crystals and fragments of old anvil tops. The formation is called 'false cirrus'. Note the different appearance of the two parts of the cloud, as shown in the photograph facing page 48. The edges of the cirrus are indefinite and fibrous, whereas the edges of the cloud composed of water droplets are clean and well defined. This is because the water droplets on the outside are continuously evaporating whereas ice crystals evaporate more slowly. The fall speeds of the finer ice crystals are also likely to be less than in the case of the water drops. For this reason, the cirrus part of the cloud will often persist long after the lower part of the cloud has dispersed.

Once a cumulonimbus is well established, it sucks into its base the many smaller thermals rising from the earth and combine them into a strong central up-current travelling at speeds up to 50 m.p.h. or more. The winds at ground level are caught up into the storm. Heavy showers, sometimes with hail, thunder, lightning and strong gusts of wind are associated with this cloud. A characteristic of a thunder storm is the sudden drop in temperature as a downdraft brings cooler air and rain from high in the cloud to the ground.

Many of the late evening storms arriving over this country in summer have drifted up in a northerly direction from the Continent. Once established, they have the energy to persist for many hours after sunset when the ground has lost its heat.

9 Rain, Snow, Hail and Thunderstorms

1. RAIN

Precipitation is the name given to all forms of moisture which is deposited on the earth from the atmosphere. It includes rain, snow, sleet and hail.

The major question is: 'Why do some clouds give precipitation and others not?' For many years scientists have been engaged in answering this question. A cloud droplet is so minute that it is impossible for it to grow, by condensation, to a size or weight big enough to fall to the earth without evaporating on the way down. To produce rain the cloud droplets must somehow join and it takes thousands of them to make one raindrop.

In 1933, a Swedish scientist, Bergeron, put forward a theory which satisfactorily explains some of the facts.

It had been observed that rain often fell from a moderately shallow cloud in winter, whereas, in summer, a cloud of twice the height would not produce rain. It was a matter of temperature. He pointed out that when a cloud reaches well above the freezing level, it contains ice particles as well as supercooled cloud droplets. The ice particles grow by collisions with the water droplets, when the moisture immediately freezes on to the ice particle. These grow into snow flakes and begin to fall. The ice crystals grow rapidly at the expense of the water droplets until they are heavy enough to fall to the ground. If they reach it in crystal form we call it snow. If they pass through air with a temperature higher than 0° C., they melt and reach the earth as rain.

It was some years before it was realised that the Bergeron theory could not explain all precipitation. Many clouds, especially in the Tropics, give plenty of rain without ever reaching freezing level. These raindrops cannot possibly result from the melting of snowflakes.

After exhaustive research and measurement, it was discovered that the size of cloud droplets varies considerably, depending on the size and nature of the condensation nuclei. The larger ones, being heavier, fall and collide with others in their path and each collision results in a merging or a coalescence of the droplets. The more turbulent the cloud is the more collisions of drops and droplets take place.

Beneath a cloud base, the air is drier and water evaporates from the surface of the drops as they fall towards the earth. It is the larger ones which survive to reach the ground.

A cloud, then, must be deep with a sufficiently strong up-current of air to enable a droplet to grow large enough to make a raindrop by coalescence.

When the drops have a diameter greater than ·5 mm., the precipitation is known as *rain*.

When the droplets reaching the ground have a diameter less than 0·5 mm. (0·02 in.), the precipitation is known as *drizzle*. It probably comes from stratus or stratocumulus clouds.

RAIN

Among the wettest places on earth are Mount Waraleale, Hawaii with an average yearly rainfall of 471·68 ins., and Cherrapungi in the Khasi Hills of Assam with 425·96 ins. The effect of mountains in forcing air to rise and cool by expansion is illustrated by these average yearly amounts in Britain: Snowdon (Cambrian Mountains) 171 ins., Borrowdale (Cumbrian Mountains) 131 ins., and in contrast Chester 27 ins., Darlington 26 ins., London 25 ins.

A CLOUDBURST

A cloudburst is a sudden and excessive downpour of rain. It is caused when strong upward air currents within a convection-type cloud prevent the raindrops from falling to the ground and large accumulations are built up. Eventually the air column is overcome, resulting in exceptional falls of rain:

Beaumont, Texas on 18th May 1923: 13·54 ins. of rain in 2½ hours.
Plumb Point, Jamaica on 12th May 1916: 15 ins. in 15 mins.
Wagga, New South Wales, Australia on 28th October 1912: 1 in. in 2 mins.
Thornton, Texas on 19th July 1922: 8·35 ins. in 40 mins.

Glazed frost occurs when the ground is frozen and rain falls, probably from a warm front overhead. The rain freezes as it touches the ground, covering everything, the trees, roads and buildings with a beautiful but treacherous coating of clear ice.

2. RAINMAKING

The two theories of rain (*a*) from ice crystals, and (*b*) from coalescence were both seized upon by man in his desire to improve on nature.

During the 1939–45 War two Americans, Irving Langmuir and Vincent Schaefler, were working on the problem of severe icing of aircraft, caused by flying through supercooled droplets. When the war was over, they turned their energies to producing rain by scattering pellets of solid carbon dioxide (dry ice) into clouds containing supercooled droplets. Their efforts sometimes met with success but the experiments, which involved using aircraft, were expensive. Meanwhile, another colleague, Bernard Vonnequt, discovered that minute particles of silver iodide, whose crystal formation closely resembles that of ice, were an equally effective agent in turning droplet cloud into snow. The three physicists joined forces. Generators capable of producing millions of silver iodide particles each second were designed and placed upwind with the intention that these particles would be carried into the air to produce rain cloud.

The experiments sometimes met with some success, but before a true and exact assessment could be made, the idea was commercialised. Hundreds of rainmakers with extravagant claims appeared in America and Australia and their services were readily purchased by farmers with thirsty land. There is no doubt that clouds of considerable thickness containing supercooled drops can be made to produce rain by seeding with silver iodide particles, but to what extent rainfall as a whole is increased cannot be assessed without keeping records over a long period.

A noteworthy experiment in rainmaking arose from the coalescence of droplets of water. Aircraft have fed clouds by spraying them with a few hundred gallons of water. These bigger drops have swept up the cloud droplets and caused heavy rainfall of thousands of gallons.

There exists also the possibility of preventing rain when that is considered desirable. In order to achieve this an abundance of particles of dry ice or silver iodide is fed into a cloud. No particle is able to collect sufficient moisture to make a raindrop and the cloud changes into trails of ice crystals and evaporates.

So far, the results of these efforts seem too variable to be regarded as reliable. The possibilities for the future may be innumerable. Man may discover the means to treat growing hurricanes and render them harmless, disperse injurious and stifling fogs, and bring clouds and rain to the deserts. A more even distribution of sunshine and rain over the earth's surface would mean the end of droughts and floods, famine and waste.

3. SNOW, SLEET AND HAIL

Snowflakes consist of a collection of interlocking ice crystals. Examine a snowflake on a dark wool background under a magnifying glass. Apart from having six sides, no two crystals are alike. In growing, the hexagon-shaped flat ice crystal may thicken into a prism or send out identical branches from the six corners which in turn send out smaller branches sideways to make the most varied and intricate patterns.

Sleet is a mixture of snow and rain. It is possible that the snow is partly melted. The ground temperature will probably be above freezing point and the snow will soon melt.

Hail. Inside a cumulonimbus cloud a larger ice particle or water drop may be caught by an upward gust carrying it up above the level where the air temperature falls to freezing point (the freezing level) and it freezes. On falling, it may collide with a supercooled water drop which gives it a coating of clear ice.

In its present form we recognise it as a hailstone. This journeying up and down in the strong currents of a storm cloud may be repeated many times before the hailstone eventually falls to the earth. If you cut a hailstone in half you will often find it made of several layers. Some of these are white (being deposits of ice from minute cloud droplets) and some are clear ice resulting from collision with bigger supercooled drops of water. Its turbulent journey is clearly recorded. Hailstones as big as golf balls have been reported in Britain and are evidence of the vigour of up-currents in a cumulonimbus.

4. A RAINGAUGE

Rain, snow, sleet and hail can all be collected and measured in a raingauge, although the measurement of snowfall by this means is seldom altogether satisfactory, and can be quite misleading either if it has to be heated to melt it (and some is lost by evaporation), or if the gauge collects or loses snow because of drifting caused by the wind.

A raingauge consists of:

(*a*) A circular metal funnel 5 ins. or 8 ins. in diameter. The top is made of stout copper and is bevelled to minimise damage. The sides are vertical for about 4 ins. before sloping into a narrow copper tube. This allows for heavy falls of rain and prevents loss through splashing and evaporation.
(*b*) A collecting jar or can.
(*c*) A metal can over which the funnel rests. As the collecting jar is inside the metal can, evaporation is avoided.
(*d*) A measuring jar.

The raingauge is erected in open ground with its rim 12 ins. above the ground.

5. THUNDER AND LIGHTNING

Electricity, carried by invisible molecules of the air called ions, is always present in the atmosphere. In a thunderstorm, or cumulonimbus cloud such as we have described at the end of Chapter 8, electricity is developed at a remarkable rate. Differences of hundreds of millions of volts are created between the top and bottom of the cloud. The exact way in which this electricity is generated is not yet known, but many theories have been put forward and, as new facts are discovered, these theories are revised. Most thunder clouds build up a negative electric charge in the lower part of the cloud and a positive charge in the top.

In a cloud composed of a mixture of ice particles and water droplets at temperatures below the freezing point, the ice particles grow into snow flakes at the expense of the water droplets. As the bigger snowflakes fall to levels where the temperatures are higher, they melt. The largest raindrops so formed break up into smaller drops because of the air resistance. It is in this process that electrical charges are apparently acquired, equal and opposite charges

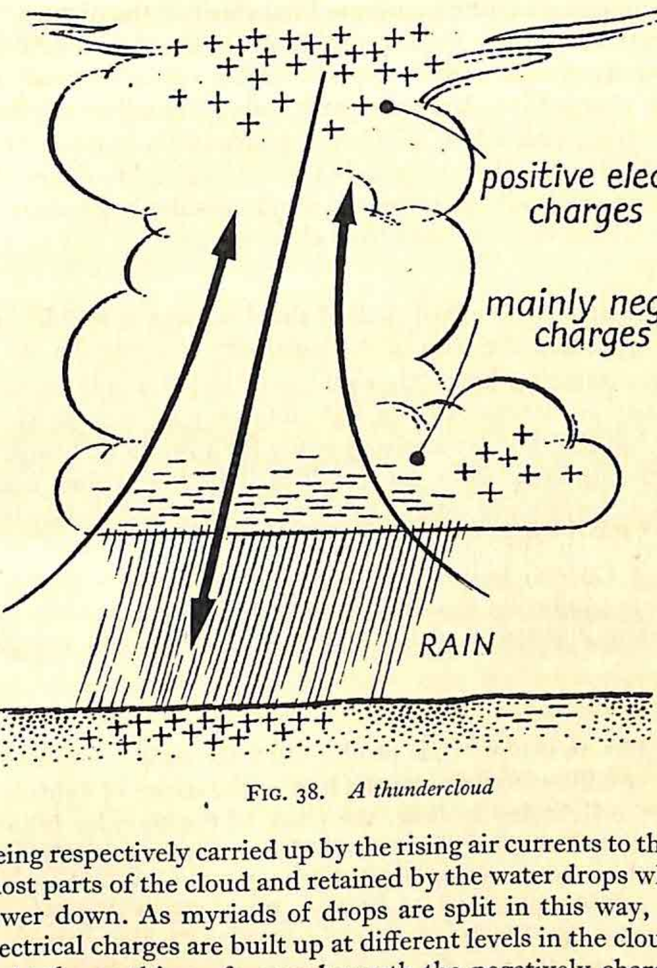


FIG. 38. *A thundercloud*

being respectively carried up by the rising air currents to the uppermost parts of the cloud and retained by the water drops which stay lower down. As myriads of drops are split in this way, very big electrical charges are built up at different levels in the clouds.

At the earth's surface underneath the negatively charged base of the cloud an opposite positive charge accumulates. At last the resistance of the air is overcome and much of the electricity from the base of the cloud is discharged into the earth in a violent flash of lightning. Recently, high speed photography capable of exposures of one millionth of a second has clarified the picture. In the flash, streams of ions pour from the base of the cloud and map out the route. As this stream approaches the earth, a stream of oppositely charged ions leave the earth, using any tall convenient projection from which to take off. The whole of the track is brilliantly lighted as the electricity rushes from the cloud to the earth. The positive charges in the top of the cloud may also be discharged by flashes within the cloud and from cloud to cloud.

In *forked lightning* the actual path of the discharge is visible, but in 'sheet' lightning the path of the electricity is inside the cloud or above the congested base of the cloud, so in the latter only the light can be seen. Sometimes distant lightning may be seen as sheet lightning but the thunder similarly is too far away to be heard.

An active thunderstorm can produce lightning flashes every few seconds, expending electrical energy at a continuous rate of a million kilowatts. When it is realised that there are, at all times, over the earth's surface, between six and eight thousand thunderstorms each producing electricity at a fantastic rate, you are able to gain some impression of the tremendous forces and energies involved.

Thunder, like an explosion, is produced by the sudden expansion of the air resulting from the terrific heat of the stroke of lightning.

When the lightning is close, the crack of the thunder follows uncomfortably soon. As light travels almost instantaneously, you can judge how far away a storm is by the length of time between the flash and the resulting thunder. A difference of five seconds roughly represents a mile.

As the flash of lightning may be more than a mile long, with many branches giving it a forked appearance, the sound of the thunder takes much longer to reach the earth from the more distant parts of the flash. In such cases it lasts for several seconds and becomes a series of explosions.

The rolling effects of thunder is probably produced by the sound echoing between the clouds or the hills. In mountainous areas it is most marked and prolonged.

Clouds with no ice particles have developed into thunderstorms in tropical areas and the problem of how the differing charges are started is one of the problems of modern research.

Most high buildings carry a lightning conductor. This is a copper rod which projects above the top of the roof with a copper strip running from the rod down the outside of the building into the ground. If a thunderstorm is overhead, positive ions will accumulate at the highest points in the neighbourhood. If a lightning conductor is fitted, it will ensure that the lightning's path will lead through the conductor safely to earth, without any severe damage to the building.

Although lightning has tremendous power and can do severe damage, there is certainly no need to regard it with fear. The chances of being struck are very slight, especially if you act sensibly. When a thunderstorm is close, avoid standing under isolated trees or near tall objects, as these project above their surroundings and will be in the path of the lightning if it strikes in that area.

In an open space, like a golf course, it is safer to lie down than stand with a storm overhead.

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10 The Meteorological Service

1. INFORMATION FROM FAR AND WIDE

Everyone is affected by the weather. The housewife with her washing, the mother with her children to dress, families on holiday, caretakers with buildings to heat and clean, road users, groundsmen, sports organisers, shopkeepers and builders, all depend on the weather as much as fishermen, farmers and aircrew. The Weatherman on television is given 5 minutes in which he tries to give us all a picture of what is likely to happen over the country as a whole. He is a spokesman for the Meteorological Office.

The actual making of a forecast is the responsibility of the senior forecaster and to help him he has a vast team.

Some members of that team are stationed in different parts of the British Isles, some are in ships at sea, some fly in aircraft and some use radio-sondes to investigate the upper air. Night and day in a non-stop service they observe the weather and send their reports through to the Headquarters of the Meteorological Office at Bracknell, Berkshire.

Obviously it is most important to the weather forecaster to know as much as possible about the conditions – temperature, pressure, humidity and winds – in the upper air as well as on the ground and at sea level.

Although aircraft are still used to investigate the air at various levels, especially over the sea, the main source of the forecaster's information about the upper air is the *radio-sonde*. This was first successfully used in 1937; since the 1939–45 War its use has spread and developed to such a degree that, over most of the world, readings are taken twice daily to heights of about 60,000 to 100,000 feet.

The radio-sonde is carried by a balloon measuring about 6 feet in diameter when inflated with hydrogen. Attached to it, but a few hundred feet below it, so that the heat of the balloon's surface shall not affect the readings, hang the recording instruments and transmitter of the radio-sonde. As well as a minute aneroid barometer, a thermometer and a hygrometer, it carries a small radio transmitter to send the information back to a ground receiving station.

At the height level reached, when the pressure inside the balloon is much greater than that of the air outside, the balloon bursts and the instruments descend by parachute. By the use of radar, the course and speed of the radio-sonde can be tracked in any weather conditions and the wind velocities at different heights can be calculated.

Most countries throughout the world maintain a weather service and information is freely and regularly exchanged between countries to their mutual advantage.

EYES IN ORBIT

American weather satellites constantly orbit the earth photographing weather disturbances from above. Their cameras have detected sandstorms in Arabia and the development of hurricanes, thus enabling ground forces to take early precautionary action. Tiros VI was launched on 18th September 1962, and was operating efficiently more than a year later.

In July 1963, Tiros VI detected Hurricane Arlene, the first of the 1963 season.

Also in July 1963, Tiros VII detected a storm 100 miles east of Saigon, Republic of South Vietnam, and within 24 hours it appeared on weather maps throughout south-east Asia.

2. AT THE WEATHER STATION

A visit to the 'Met' office at a local airfield is easily arranged as the staff are most willing to co-operate. The office is usually found in the centrally situated block of buildings where the Control Tower commands a view of all the runways.

The persistent rattle of a teleprinter greets you on entering the buildings. No doubt you have seen one of these machines on a television sports programme. The teleprinter, in many ways similar to a typewriter, prints or types a message which is electrically conveyed as it is being typed on another machine perhaps 200 miles away. It enables the latest information to be relayed all over the country in a matter of minutes.

A forecaster and two assistants are usually on duty. Apart from observing, it is their responsibility to interpret the forecasts and give advice, always bearing in mind the local conditions which can have a big effect on the weather.

Looking around the office you see one or two large mercury barometers fixed to the wall. They work in the same way as the one on page 42, but as accuracy is vital, especially for aircraft landing, there are certain corrections which have to be made to allow for the expansion and contraction of the mercury as its temperature rises and falls and for the height of the station above sea level. You will notice that the top of the column of mercury is domed. This is known as a *meniscus*. Make sure your eye is level with the top of this dome when you take a reading.

On a nearby shelf, in a glass case, there is a barograph, which records the rise or fall of the air pressure continuously. The thin flexible lid of a vacuum capsule (similar to that found in an aneroid barometer), responds to the changes in atmospheric pressure. Its movement controls a pen which marks a continuous line on a chart wrapped around a slowly rotating clockwork drum.

Two dials are on the wall showing the wind speed in knots and the wind direction in degrees. They are connected with the 3-cupped anemometer and the wind vane which can be seen at the top of two poles placed well clear of the roof of the building and 33 feet from the ground.

A visibility chart giving the direction (in degrees) and distances of various landmarks hangs on the wall.

Cloud photographs, codes and reference tables are pinned to the walls and a bench running the length of the room is covered with weather maps of the North Atlantic and the British Isles. By looking at the charts for 0000, 0600 and 1200 hours it is possible to follow the movement and growth of the various disturbances.

Out in the open, away from the building, is a fenced-in enclosure containing a white box with fluted (or 'louvred') walls known as a 'Stevenson Screen'. It stands on legs 4 feet above the ground so that the temperature of the air inside the box is not affected by the ground or by buildings. The sides of the screen are louvred to allow air to pass freely in and out whilst preventing the sunshine or rain from directly entering the box.

Inside the screen are found:

1. A wet and dry bulb hygrometer as described on page 33.
2. A hygrograph which records on a revolving drum a continuous line showing the changes in the humidity of the air. The stretching and contraction of a small collection of human hairs cause the instrument to work (see pages 33 and 34).
3. A maximum thermometer in a horizontal position records the highest temperature of the day. Just above the bulb there is a narrow portion of the tube similar to that found in a clinical thermometer. As the temperature rises, the mercury is forced past this constriction but is unable to return unless the thermometer is shaken.
4. A minimum thermometer also hangs horizontally. It records the lowest temperature of the day or night. Inside the stem is a glass index which is drawn along towards the bulb as the spirit in the thermometer contracts. When the temperature rises and the spirit expands, the index is left in position marking the lowest temperature reached.

5. A thermograph which makes a continuous record of the temperature changes.

In the same enclosure is a rain gauge which works in the same way as the one described on pages 87 and 88. A thermometer for measuring the lowest ground temperature lies horizontally just above the grass, resting across a small 'crutch'. This thermometer is similar to the minimum thermometer, and contains a glass index and spirit.

A *cloud searchlight* is used at night to determine the height of low cloud. On the side of an upright post is a simple instrument for measuring the angle of elevation. The cloud searchlight is a fixed distance from this post and shines vertically upwards to make a spot on the underside of any cloud. This spot is sighted on the instrument, the angle noted, and the height of the cloud is calculated or read from a prepared chart.

The *sunshine recorder* is often placed on the roof. This instrument measures bright sunshine.

In the British Isles the Campbell-Stokes pattern of instrument is used. The sunshine passes through a spherical lens which focuses the image of the sun on a graduated card, causing it to char. The hours of sunshine are measured by the length of the charred line. Sunshine must have a certain intensity before the card is affected. When the sun is low in the sky near sunrise or sunset, owing to the absorption and scattering of the sunlight in its long transverse journey through the atmosphere, the sunlight is not intense enough to be recorded.

The mean hours of sunshine for most places in the British Isles range from less than two hours daily in the months of November, December and January, rising to about seven hours daily in the months of May and June. Two of the sunniest places in the British Isles are Eastbourne and Jersey with a mean daily sunshine of 8·31 and 8·5 hours respectively for the month of June.

Meteorological tables of the daily average of bright sunshine show not only a difference for places of different latitude, but also a marked difference between inland areas and the more cloud-free coastal resorts.

For the period 1931–60 the daily means in hours are shown:

	BIRMINGHAM	BLACKPOOL	NEWQUAY (CORNWALL)
January	1·37	1·56	1·90
February	2·06	2·46	2·75
March	3·16	3·76	4·29
April	4·63	5·70	6·08
May	5·39	6·92	7·02
June	6·00	7·22	7·33
July	5·35	5·96	6·33
August	5·13	5·75	6·31
September	3·90	4·43	5·00
October	2·77	3·09	3·51
November	1·59	1·75	2·33
December	1·22	1·21	1·73

3. WORKING TO A ROUTINE

At about 10 minutes to every hour an assistant examines the instruments and the weather and enters his observations in a book. Returning to the office, he codes his message into a series of numbers arranged in groups of five.

At five minutes to the hour, he types these numbers on the teleprinter to his Group H.Q. whence they are sent, with the observations of other stations in the group, to the H.Q. of the Meteorological Office at Bracknell.

Here is a coded message from station 826:

81450 65616 10415 855++ 14830 88627

This message says:

81405: The sky is completely covered with cloud. The wind is from the S.E. and its speed is 5 knots.

65616: Visibility is about nine miles. There is continuous rain at present and it has been raining during the past hour.

10415: The atmospheric pressure at M.S.L. (mean sea-level) is 1,010·4 mbs. and the temperature is 15° C.

855++: There are 8/8ths stratocumulus cloud at a height of 2–3,000 ft. Medium and high clouds cannot be seen.

14830: The dew point is 14° C. The barometer after being steady has dropped 3 mbs. in the last three hours.

88627: The height of the 8/8ths layer of stratocumulus cloud is 2,700 ft.

At 10 minutes past the hour, Bracknell begins to send out to all stations the observations that have been received from all parts of the country. It takes until 10 minutes to the next hour to complete the broadcast.

The 5-figure code is international and has the same meaning wherever it is received.

The reports from ships and aircraft give the latitude and longitude so that the information can be correctly plotted on a map.

Every three hours at 0, 3, 6, 9, 12, 15, 18, 21 hours by Greenwich Time, i.e. midnight, 3 a.m., 6 a.m., 9 a.m., noon, 3 p.m., 6 p.m., 9 p.m., an assistant begins the work of plotting a *synoptic chart* by decoding the messages and plotting the information on a map. He uses two pens, one for red ink and the other black but he binds them together with elastic bands and with practice can switch from one colour to the other with extraordinary ease and speed. In order to make examination of the completed chart easier, certain parts of the information are printed in red and the rest in black.

Fig. 39 shows how our message would appear on the synoptic chart.

When all the observations have been similarly plotted, the fore-

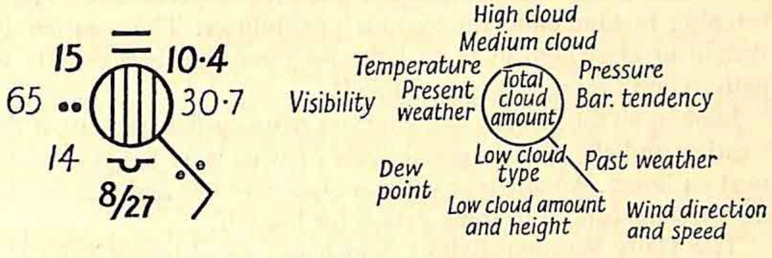

FIG. 39. *Symbols in lighter type are normally written in red.*

caster studies the air pressures and winds and draws in the isobars. Sudden wind changes and big differences in the dew points immediately suggest different air masses and the existence of a front. It must be remembered that weather development is a continuous study and that the forecaster will of necessity refer to previous charts to follow the progress of any disturbances.

He must then examine the map for any new development. There may be signs of a fresh depression forming on a trailing cold front or a secondary depression growing to upset all previous calculations. A ridge of high pressure may build up over the country and hold back or deflect the low pressure systems. A slight change of wind can bring air from tropical sources to replace arctic cold.

These changes can in some ways be detected and understood more easily from the behaviour of air at higher levels. It is only since the Second World War that the number of stations using radio-sonde balloons to investigate the upper air has increased sufficiently to make detailed maps possible.

This means that the Senior Forecaster and his colleagues, as they settle down to forecast the weather 24 hours ahead, have information concerning the pressure, temperature, humidity, wind direction and strength from the ground up to about 20 miles. Forecast weather maps which are prepared every six hours are known as *prebaratics*.

On television, the weatherman presents a prebaratic. When listening to him, note the various possibilities. The weather in Britain or elsewhere in these latitudes rarely behaves exactly to pattern and timing is always difficult.

Look upon the forecast as giving you an up-to-date picture of the weather and the various possibilities of what may happen in the next 24 hours. An amateur with an observant eye and one or two instruments can fill in some details for himself.

The Daily Weather Report, which can be obtained from the Director General, Meteorological Office, London Road, Bracknell, Berkshire, costs but a few pence but it is packed with most useful information. It includes weather charts of much of the Northern Hemisphere and also of Western Europe at different times. It is possible to examine the progress and behaviour of weather systems as they cross the Atlantic. On the reverse side the observations of between 50 and 60 land stations and eight weather ships are given in code for different times of the day.

WEATHER SHIPS

The United Kingdom co-operates with France, Holland and Norway in maintaining a constant watch at five ocean weather stations in the North Atlantic. The Meteorological Office operates four ships of which two are always on station.

Nearly 700 ships of the British Merchant Navy voluntarily observe and report on the weather. Of these, 480 make full reports four times daily.

4. HISTORY OF THE SERVICE

It was not until the 1840s, with the introduction of the electric telegraph, that study of the existing weather on a map became possible. Until then any information collected took so long to send that it had nothing but historical interest to the seamen or farmers who were seeking it.

In 1849, James Glaisher, a member of the staff of the Royal Observatory, Greenwich, made attempts to collect information about the weather with the help of the *Daily News* and the Electric Telegraph Co.

In 1855 the Meteorological Office was formed as a Department of the Board of Trade with Admiral Fitzroy as its first Director. Using information from France and this country, daily weather forecasts and gale warnings were issued from 1860.

From 1868, observations were received from Corunna in north-west Spain; in 1869 from Norway; in 1873 from Sweden; in 1887 from Germany and in 1894 from the Azores.

In 1906 observations from Iceland and the Faeroes began to reach Britain through the cables of the Great Northern Electric Co. In 1907, the first wireless reports were received from ships of the Royal Navy and two years later from Atlantic liners.

Although the 1914–18 War interrupted the growth of the service, it also served to emphasise the need for international co-operation and a 'pooling' of up-to-date weather reports.

Since then great strides have been made in communications and in research. Today the meteorological service is a well co-ordinated body covering the whole world.

11 A School Weather Station

1. A STATION AND INSTRUMENTS

In setting up a school station, it is a mistake to buy an expensive screen and all the instruments without a great deal of preparation. It is of little value just to take readings of the instruments without realising why they change from hour to hour and season to season. It is not good enough just to know that air has pressure and that this is measured on a barometer. What causes the pressure? How does the barometer work? What is causing it to rise or fall? Will this change affect the wind? Will the air be warmer or colder, drier or more moist? Will there be more or less cloud, etc.? All these factors depend on one another and a far greater understanding of them can be gained when you know how to use the apparatus to its best advantage.

The minimum requirements are:

1. A suitable site.
2. A screen to house the thermometers.
3. A rain-gauge.
4. A barometer.
5. A display board.

SITE

An open, level, grass-covered surface well away from trees and buildings is required on which a screen and a rain-gauge can be set up with a minimum distance of ten feet between them.

SCREEN

Particulars of a Stevenson type screen and its main purpose are set out on page 95.

1. It is possible to 'do it yourself' and buy wood, cut to size and shape, ready to assemble and paint, thereby making a considerable saving.
2. A pamphlet on making a screen can be obtained from H.M.S.O. for schools where the woodwork department can undertake the task.

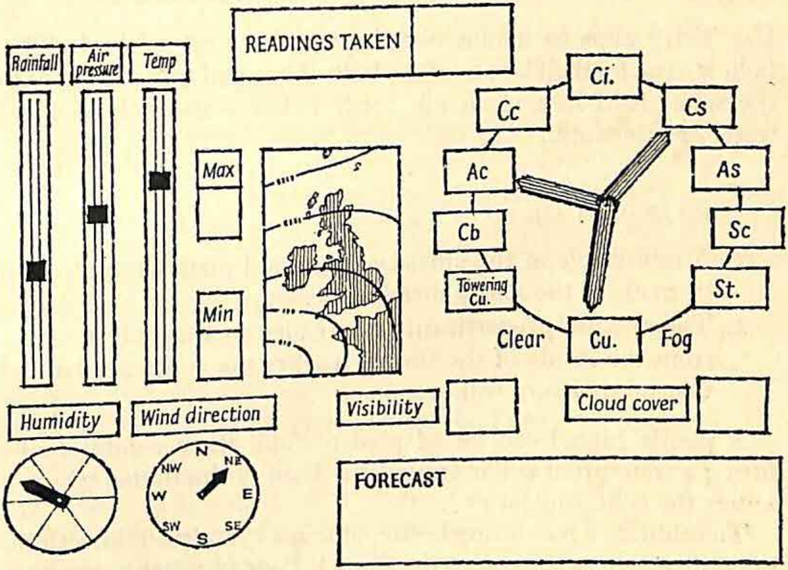

FIG. 40. *School weather display board*

3. If both of the above suggestions are too expensive, it is possible to improvise, viz. the outside of the screen successfully used at a primary school is made from a packing case. The inner compartment is made of peg board. Between the two is a gap of 2–3 ins. to allow air to pass freely around the box. The roof, about 6 ins. longer and wider than the box, is separated from the sides by a similar gap.

The peg-board fittings used to hold the instruments also assist in keeping the screen well-ventilated.

THE WET AND DRY BULB HYGROMETER

Use Terry clips to mount two thermometers on a board. Fit a hollow-type football lace over the bulb of one and trail the lace into the water held in a clean ink bottle below – use only distilled water or rain water.

RAIN-GAUGE

1. A rain-gauge of the official pattern and material might well be made in the school metal workshop.
2. The essential properties of a rain-gauge are that only moisture from the inside of the funnel reaches the collecting jar and that no moisture will evaporate.

A plastic funnel can be adapted to fulfil these conditions by fitting a waterproof collar around the stem of the funnel where it enters the collecting jar or bottle.

To calibrate a measuring bottle, obtain a cylindrical tin with the same diameter as the top of the funnel. Pour in water to exactly a depth of 1 in. Transfer this water into your measuring bottle which must have upright sides, mark off the level – this heigh represents 1 in. of rainfall. By dividing the height into 10 equal lengths you can make a scale to measure 1/10th or 0·1 of an inch of rainfall. Further divisions will mean greater accuracy.

BAROMETER

1. A simple mercury barometer as shown on page 42 is easily set up.
2. It is recommended that a good aneroid barometer should be purchased.

It is not nearly so important to find whether the atmospheric pressure is 29·8 ins. or 29·75 ins. barometric as it is to measure the changes of pressure from hour to hour.

A great deal of enjoyment and information can be gained from 'home-made' barometers.

A kilner (from which some of the air has been expelled) fitted with a piece of rubber sheeting as described on page 16 makes a crude but responsive barometer. There are many simple ways in which the movement of the rubber can be magnified and recorded on a scale.

Another effective and more durable model can be made from a plastic oil can. Expel some of the air by squeezing the sides, and seal the end with plastic cement. Thread is fixed to the side of the oil can, passed a number of times round a cylindrical rod or needle, over a pulley wheel and weighted or attached to a spring to keep a tension on the thread. To the end of needle or rod, which is free to turn, is fixed a pointer.

WIND VANE AND ANEMOMETER

It is certain that much can be learnt by gauging the wind velocity by observing the movement of trees, smoke and low clouds, in conjunction with the Beaufort Windscale. It is equally certain that a wind vane and an anemometer are the most popular instruments to make because their movements are big and constant.

Some secondary schools with suitable workshops have made almost professional models with weather-proof bearings and wired so that the direction of the vane, completing an electrical circuit, lights the appropriate bulb on a dial inside the building. Similarly the anemometer is wired to a trip counter, so that the wind speed is recorded.

The models described below, although less ambitious, are just as effective and can be made in any school.

WIND VANE

A cross-halving joint is recommended to join two pieces of wood ($1\frac{1}{4}$ ins. square) together to give the four directions N. S. E. and W. These letters can be cut from thin metal and fitted into slots and pinned at the ends of the wood.

The body of the vane can be made of balsa wood and cut to any shape. The main necessity is to have a large, preferably metal, fin which causes the vane to point into the wind.

A smooth, long-lasting bearing can be made by closing one end of a thick glass tube which rotates over the end of a steel bolt.

ANEMOMETER

The anemometer is similarly pivoted using a bolt and a glass tube glued through the wooden joint. The cups consist of plastic funnels, one red, and others a different colour as this helps when counting the number of revolutions in a set time. To fix the cups, drill holes horizontally through the arms. A dowel rod is glued and pinned into the holes with 1–2 ins. projecting on one side. The funnel stem is shortened and fixed over the projecting dowel.

VISIBILITY AND DIRECTION CHART

A 360° perspex protractor is fastened to a table with 0° pointing to north. Make a list of various landmarks near and far and note their directions from the protractor. Obtain a large-scale ordnance survey map, find the school and the landmarks and measure the distances between. Calculate the true distances and enter them on the visibility chart.

A magnetic compass can be made by magnetising two razor blades and gluing them to the underside of a cardboard disc which is pivoted by using part of a press stud, or a pin driver and a stout pin. Use brass nails to make the points of the compass.

A SOIL THERMOMETER

This is used to take readings at different depths in the soil. It can be protected in a copper tube. Cut away part of the side of the tube so that readings can be taken. A wooden handle and a spike can be fitted to the ends.

DISPLAY

Observations on the weather should be clearly and easily displayed on a board. On the example shown as in Fig. 40, which has been successfully used in a school for many years, the rainfall, atmospheric pressure and air temperature are shown by adjusting a sliding strip of coloured formica.

Photographs of the ten main types of cloud are on view divided into three sections – high, medium and low – with a pointer for each section. The pointers are rotated to indicate those clouds present in the sky.

Where information has to be written in, the surface is covered with perspex and a chinagraph pencil is used. The board includes:

1. A synoptic chart of the British Isles;
2. A situation and forecast;
3. Max. and min. temperatures of previous 24 hours;
4. Visibility;
5. Cloud cover;
6. Wind velocity;
7. Relative humidity.

2. SUGGESTIONS FOR WEATHER STUDY

1. Much more can be gained by making observations every hour for a number of days on end at different times of the year, than by taking isolated readings.

2. Records should be made of rainfall, wind velocity, air pressure, temperature, humidity, etc., and a number of these, in different colours, should be plotted on the same graph to emphasise the connection between them.

3. Obtain a Daily Weather Report from the Meteorological Office.

4. Listen to weather forecasts and obtain a full copy from one of the daily newspapers.

5. Collect photographs and pictures of clouds, and compile a cloud atlas.

6. Collect newspaper cuttings on storms, hurricanes, and other weather news.

7. Visit a local meteorological station.

8. Make records in graph of:

   (*a*) Hourly observations of ground temperature.
   (*b*) Hourly observations of air temperature.
   (*c*) Hourly observations of pond temperature.

9. Hourly observations of atmospheric pressure, humidity and rainfall.

10. Hourly observations of atmospheric pressure, wind velocity and humidity when fronts are crossing the country.

11. Hourly observations of wind velocity, humidity and rainfall.

12. Hourly observations of humidity and air temperature.

13. Take the temperature of soil at various depths.

14. Examine seaweed, fir cones, 'gut hygrometers', salt, etc., and compare with relative humidity.

15. Take hourly readings from the wet and dry bulb hygrometer after sunset on a cloudy night and compare with similar readings on a clear night.

16. When the early morning sky is clear, look for the beginnings of cumulus clouds. Study their growth, especially the top edges, and determine whether the air stream is stable or unstable.

17. Note how the cloud bases of cumulus become higher during the day.

18. In towering cumulus compare the separate towers rising and sinking with the action of boiling water.

19. Look for the change of the top of a towering cumulus from water droplets to ice particles.

20. Note the freshening of the wind as air is sucked into an advancing thunderstorm.

21. Record the falling temperature during a thunderstorm.

22. Study the evaporation of cumulus-type cloud:

(*a*) In late afternoon;
(*b*) When cloud convected over the land moves over a clear sea, and vice versa;
(*c*) When a warm front approaches.

23. If you know a warm front is approaching look out for mares' tails, thickening layers of cloud, etc. Examine the sky for haloes and other phenomena.

24. During the passage of a cold front keep constant watch on the wind direction and strength, humidity, the barometer, and state of sky.

25. Collect and examine hailstones and snow crystals.

26. Determine if the wind changes with height by studying the movement of clouds at all levels.

27. Look for cloud formation at all levels above hills and high ground.

28. Use a pole or stick of known length and measure the direction and length of its shadow at set times during the summer. Repeat at similar times in the winter and compare the angle of elevation of the sun.

29. Anticipate frost and fog warnings by observing the signs.

30. Note the temperature and wind changes as fog lifts into stratus.

31. Prove that colder air sinks downhill by taking the minimum temperature at the top of a slope and in the hollow below.

32. Knowing that hair stretches when moist and contracts when dry, design and make a hygrometer to measure the changes.

12 Glossary of Meteorological Terms

ANABATIC See KATABATIC.

AURORA BOREALIS 'The northern dawn', is a glow seen in the sky near the northern horizon at night. It may appear in several forms:

1. As an arc low across the sky, sometimes with rays piercing upwards from it;
2. As rays or 'bundles' of rays reaching up to a corona or 'crown' at the zenith. (When fully developed the shafts of light in the sky are arranged like the frame of an umbrella);
3. As hanging curtains or winding snakelike draperies. They are caused by electrical discharges from the sun and appear most frequently in places one to two thousand miles from the magnetic pole at heights of 60 to 100 miles. They are mostly seen in the latitude of northern Norway, Iceland, Greenland and parts of Canada.

AURORA AUSTRALIS is the name given to the similar phenomenon in the Southern Hemisphere.

CONTRAILS or CONDENSATION TRAILS Formed when aircraft fly at great heights. There are two main causes:

1. The mixing of hot, moist gases from the engine exhaust with the surrounding cool air causes the vapour to condense in a thin white trail some distance behind the aircraft. This trail grows bigger as the mixing continues and if the surrounding air is very moist, it can become dense and persistent. If the air is dry the trail of water droplets or ice particles will slowly evaporate.

2. As an aircraft flies at speed through the air, there is a reduction of air pressure behind the wings. If the air is sufficiently moist, condensation will result as it is chilled on expansion. The trails may extend the whole length of the wings or be confined to the vortices at the wing tips.

CORONAE Coloured rings close around the sun or moon, caused by the light rays bending round small droplets of water of uniform size. A street light has a corona when viewed through a fog or through a window which is 'steamed up' – covered with small droplets of water. A corona is bluish on the inside and reddish on the outside.

FÖHN WIND When a moist air stream is forced to rise over the Alps, the air expands because of the fall in pressure and its temperature falls, resulting in the formation of extensive cloud and rainfall on the windward slopes. The reduction of temperature of the rising air is only at the saturated adiabatic rate (see page 114), i.e. only about 2½° F. per thousand feet, because of the heat released in condensation offsetting the effect of expansion. When the air reaches the lee side it is relatively dry. The air's temperature increases again as the air is compressed in descent on the lee side, and now that it is dry its temperature rises at the full rate produced by compression of dry air: about 5° F. per thousand feet. Thus the air on the lee side becomes several degrees warmer than on the windward side. The sudden arrival of the Föhn wind can overnight melt some of the snow and ice, bringing a touch of spring in the midst of winter. The CHINOOK (snow eater) of Canada is a similar wind bringing warm dry air to the eastern slopes when a westerly wind is forced over the Rockies.

HALOES Rings of light which encircle the sun or moon, caused by the refraction of light in passing through ice crystals of a layer of cirrostratus or altostratus. As the ice crystals are always symmetrical, the beams of light are refracted at fixed angles 22° and 46°. The 22° halo is brightest and has a reddish tint inside and a bluish outside. A SUN PILLAR is a pillar of light extending vertically through the sun. It is caused by the reflection of the sun's rays from the horizontal bases of ice crystals as they settle through a high cirrus cloud. The pillar reflects the sun's colour which is usually white, but, if setting, the pillar too will appear yellow to red. When the snowflakes oscillate as in a light wind, a horizontal pillar of light can also be formed giving the striking phenomenon of a cross in the sky. MOCK SUNS or PARHELIA occur where a horizontal pillar creases the 22° halo; two points of light of greater brightness are formed. These are known as mock suns.

ISALLOBARS Lines drawn on the weather chart joining places which have equal values of barometric tendency (i.e. equal amounts of pressure change over the last three hours). They are a useful guide in showing the probable movement of depressions and anticyclones.

JET STREAMS During the 1939–45 War it was discovered that the winds at heights of five to eight miles commonly blow at speeds of over 100 m.p.h., very occasionally at well over 200 m.p.h., usually from a westerly point. These very strong winds are more or less confined to strips or belts of the atmosphere only 100 to 200 miles wide, though they may extend for 1,000 to 2,000 miles along the line of the wind. Aircraft may pass into one of these wind streams and be carried rapidly along in the direction of the wind unless their speed and heading are suitably adjusted. For aircraft intending to fly in the direction of the jet stream a great saving of fuel may be obtained, whereas flying against the jet stream reduces the range of the aircraft.

Depressions and anticyclones on the surface weather may develop with, and are to some extent carried along by, the jet streams.

KATABATIC Winds formed in hilly or mountainous districts when the ground loses its heat by long-wave radiation and the air in contact with it is cooled, becomes more dense and sinks down the slopes into the valley bottom where it flows as a river of cold air. These winds bring frosts to valleys and hollows and cause the cold vigorous winds found in the fjords of Norway and Greenland. ANABATIC (reverse of Katabatic) is a day time breeze which blows up the valleys in hilly country. The sun heats the ground. The air in contact with it is warmed and rises so that a flow of air up the slopes is started.

In many ways these winds are similar to land and sea breezes with a reverse circulation aloft feeding the surface wind.

LAPSE RATE The decrease of temperature with height.

The dry adiabatic lapse rate: a bubble of rising air cools at the fixed rate of 5·4° F. (approx. 3·3° C.) per 1,000 feet as long as it is not saturated, i.e. when there is no cloud.

The saturated adiabatic lapse rate: when the bubble of rising air becomes saturated and cloud forms, latent heat is released and the lapse rate is reduced to approximately 2·5° F. (1·4° C.) per 1,000 feet.

The environment lapse rate: is not fixed but varies with the airstream.

MILLIBAR (mb.) One millibar equals a force of 1,000 dynes pressing upon an area of one square centimetre.

THE MISTRAL A very strong, cold, dry, northerly or north-westerly wind which blows through the narrow Rhône Valley to the Mediterranean coast. The Alps funnel the winds into the valley where velocities of 85 m.p.h. have been recorded.

MOCK SUNS or PARHELIA See HALOES.

RAINBOWS If you stand with your back to the sun and spray the garden, it is a simple matter to regulate the spray to form a miniature rainbow. One in the sky is similarly formed by rays of light from the sun, which is behind the viewer, shining on drops of water in front of the viewer. The rays of light are bent and reflected by the drops of water back in the direction of the sun but towards the ground. The angle between the sun, raindrop and observer is a fixed angle depending on the colour of the light; this produces a pattern of circular arcs of different colours.

A primary bow: from the inside is coloured violet, blue, green, yellow, orange and red.

A secondary bow: with the colours in reverse order and less intense, can often be seen well outside and separated from the primary bow.

ST. ELMO'S FIRE In certain conditions of the atmosphere a glowing of the air around the tops of trees, ships' masts or anything projecting into the sky, may be seen. The glow is caused by the building up of electricity on the projections. It is not dangerous but indicates a big difference of electric charge between earth and cloud and could form a suitable track for a flash of lightning.

SFERICS Derived from the word *atmospherics*. Electrical discharges – the main source is lightning and heavy storms – are picked up by sferic units by means of a radio direction finding system. The information giving time and direction is flashed to the master control station of the network where the exact location and intensity of the disturbance is pinpointed. Discharge fixes have been accurate within 60 miles over a distance of 3,000 miles. The value of sferics lies in obtaining information from deserted tracts of land and sea, for the preparation of shipping and aircraft forecasts and in tornado detection.

SQUALL A strong wind that rises suddenly and lasts for several minutes before it finally dies away. It is particularly associated with the strong veering of the wind and a line of low black cloud giving heavy rain and hail which are typical of a vigorous cold front. It must not be confused with a gust; this is a momentary fluctuation in the wind strength caused by eddies which, in turn, are caused by friction with the earth's surface.

SUN PILLAR See HALOES.

SUNRISE AND SUNSET The lower layers of the air contain a high proportion of dust and small particles. When the sun is low in the sky the light waves travel a long oblique journey through the atmosphere. The small particles scatter the light rays and only those with the longest wave lengths, mainly red, orange and yellow, get through to the viewer.

TROPICAL STORMS with wind speed in excess of 74 m.p.h. are known by various names in different parts of the world. Those occurring in

(*a*) Gulf of Mexico, West Indies and Florida are known as *hurricanes*;
(*b*) Arabian Sea, Bay of Bengal and Northern part of Indian Ocean as *cyclones*;
(*c*) China Sea and Coasts of Japan as *typhoons*;
(*d*) Phillipines as *traguios*;
(*e*) Timor Sea and North West Australia as *willy-willies*.

13 Tables

TABLE 1

THE BEAUFORT SCALE OF WIND FORCE

Beaufort Number	*Limits of velocity in m.p.h. at 33 feet above ground level.*	*Description of wind in forecasts.*	*Noticeable effect of Wind on land.*
0	Less than 1	Calm	Smoke rises vertically.
1	1–3	Light	Direction shown by smoke drift but not by vanes.
2	4–7	Light	Wind felt on face; leaves rustle; wind vanes moved.
3	8–12	Light	Leaves and twigs in motion Wind extends a light flag.
4	13–18	Moderate	Raises dust, loose paper, and moves small branches.
5	19–24	Fresh	Small trees in leaf begin to sway.
6	25–31	Strong	Large branches begin to move. Telephone wires whistle.
7	32–38	Strong	Whole trees in motion.
8	39–46	Gale	Twigs break off. Progress generally impeded.
9	47–54	Gale	Slight structural damage occurs. Chimney pots removed.
10	55–63	Strong gale Storm	Trees uprooted. Considerable structural damage.
11	64–75	Strong gale Storm	Damage is widespread, seldom experienced in Britain.
12	Above 75 m.p.h.	Strong gale Storm	Countryside is devastated.

TABLE 2

ATMOSPHERIC PRESSURE

Inches and millibars 1 in. of mercury = 33·8639 mbs.

Ins.	*Mbs.*	*Ins.*	*Mbs.*	*Ins.*	*Mbs.*
25	846·6	27	914·3	29	982·1
25·5	863·5	27·5	931·3	29·5	999·0
26	880·5	28	948·2	30	1015·9
26·5	897·4	28·5	965·1	30·5	1032·8
				31	1049·8

TABLE 3

TEMPERATURE

Centigrade and Fahrenheit

$C. = \frac{5}{9}(F. - 32^\circ)$ $F. = 32^\circ + \frac{9}{5}C.$

°F.	°C.	°F.	°C.	°F.	°C.	°F.	°C.
+104	+40	+81	+27·5	+57	+14	+33	+ 0·5
103	39·5	80	26·5	56	13·5	32	0
102	39	79	26	55	13	31	− 0·5
101	38·5	78	25·5	54	12	30	− 1
100	38	77	25	53	11·5	29	− 1·5
99	37·5	76	24·5	52	11	28	− 2
98	36·5	75	24	51	10·5	27	− 2·5
97	36	74	23·5	50	10	26	− 3·5
96	35·5	73	23	49	9·5	25	− 4
95	35	72	22	48	9	24	− 4·5
94	34·5	71	21·5	47	8·5	23	− 5
93	34	70	21	46	8	22	− 5·5
92	33·5	69	20·5	45	7·5	21	− 6
91	33	68	20	44	6·5	20	− 6·5
90	32	67	19·5	43	6	19	− 7
89	31·5	66	19	42	5·5	18	− 8
88	31	65	18·5	41	5	17	− 8·5
87	30·5	64	18	40	4·5	16	− 9
86	30	63	17·5	39	4	15	− 9·5
85	29·5	62	16·5	38	3·5	14	−10
84	29	61	16	37	3	13	−10·5
83	28·5	60	15·5	36	2	12	−11
82	28	59	15	35	1·5	11	−11·5
		58	14·5	34	1	10	−12

Table 4

WIND SPEED

Knots and miles per hour

1 Knot = 1·15155 m.p.h. = 0·51479 metres per second.

Knots	*m.p.h.*	*metres/sec*	*Knots*	*m.p.h.*	*metres/sec*
1	1·2	0·5	55	63·3	28·3
5	5·8	2·6	60	69·1	30·9
10	11·5	5·1	65	74·9	33·5
15	17·3	7·7	70	80·6	36·0
20	23·0	10·3	75	86·4	38·6
25	28·8	12·9	80	92·1	41·2
30	34·5	15·4	85	97·9	43·8
35	40·3	18·0	90	103·6	46·3
40	46·1	20·6	95	109·4	48·9
45	51·8	23·2	100	115·2	51·5
50	57·6	25·7	105	120·9	54·1

Feet	*Metres*	*Miles*	*Feet approx.*	*Km.*
1	0·31	1	5,000	1·61
5	1·52	2	10,500	3·22
10	3·05	3	16,000	4·83
20	6·10	4	21,000	6·44
50	15·24	5	26,000	8·05
100	30·48	6	32,000	9·65
300	91·44	7	37,000	11·26
1500	457·19	8	42,000	12·87
		9	47,000	14·48
		10	52,000	16·09

14 Sources for Weather Study

FOR GENERAL READING

Clausse and Facy, *The Clouds* (Evergreen Profile Books).

R. Kay Gresswell, *The Weather and Climate of the British Isles* (Hulton).

F. K. Hare, *The Restless Atmosphere* (Hutchinson).

Richard Inwards, *Weather Lore* (Rider).

R. M. Lester, *The Observer's Book of Weather* (Frederick Warne).

Ludlam and Scorer, *Cloud Study* (John Murray).

J. S. Sawyer, *The Ways of the Weather* (A. & C. Black).

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Scorer and Wexler, *A Colour Guide to Clouds* (Pergamon Press).

L. P. Smith, *Weathercraft – simple experiments in practical meteorology* (Blandford).

Sir O. G. Sutton, *Understanding Weather* (Penguin).

I. R. Tannehill, *Hurricane Hunters* (Dodd, Mead & Co., New York).

T. H. Whitney, *The Young Scientist's Approach to the Weather* (Frederick Warne).

FOR YOUNGER READERS

Irving Adler, *Weather in Your Life* (Dennis Dobson).

R. S. Barker, *The Study Book of Weather* (Bodley Head).

A. O. Chesters, *Weather* (E.S.A.: Information Book series).

G. H. Dobinson [Editor], *The Weather and the Earth* (Longmans, Green: Science on the March series, Unit Three).

R. V. Feravolo, *Junior Science Book of Weather Experiments* (Ambler).

Peter Hood, *The Atmosphere* (Oxford University Press).

H. C. King, *Look at the Weather* (Hamish Hamilton).

I. Podendorf, *Junior Time Book of Weather Experiments* (Muller).

R. Wyler, *The First Book of Weather* (Mayflower Press).

PRACTICAL WORK

J. M. Branson, *Watching our Weather* – handbook for teachers (Chambers: Starting Science series).

Glasspool and Laybourn, *Foundations of Science* – Books 1 and 2 (University of London Press).

John Rumming, *Make and Use Models* (University of London Press).

FOR MORE ADVANCED WORK

Sir David Brunt, *Weather Study* (Nelson 1942).
E. S. Gates, *Meteorology and Climatology for Sixth Forms and Beyond* (Harrap).
G. Manley, *Climate and the British Scene* (Collins).
A. A. Miller and M. Parry, *Everyday Meteorology* (Hutchinson).
D. E. Pedgley, *Elementary Meteorology* (H.M.S.O., M.O.707).
Sir O. G. Sutton, *The Challenge of the Atmosphere – the Science of Meteorology* (Hutchinson).
Monthly Magazine, *Weather* (The Royal Meteorology Society).

H.M.S.O. Publications
Cloud Types for Observers (M.O.716).
Observer's Handbook (M.O.554).
Some Typical Weather Maps (M.O.632).
Weather Map – an introduction to weather forecasting (M.O.595).
Daily Weather Report.
The Meteorological Glossary (M.O.729/A.P.827).
Your Weather Service – The Meteorological Office and How It Can Help You.

Visual Material
(*a*) *Pictures:*
Observing the Clouds – coloured wall pictures of eight British cloud types, with notes on each (Purnell Educational Publishers).

(*b*) *Wall Charts:*
1 The Weather – Fronts (Educational Productions Ltd).
2 The Weather – Formation of Clouds (Educational Productions Ltd).
3 The Weather – Precipitation (Educational Productions Ltd).
4 The Weather – The Map (Educational Productions Ltd).
5 Behind the Weather Map (Pictorial Charts Unit).

(*c*) *Film Strips and Slides:*
Running a School Weather Station – 2 strips, in colour, with notes (Diana Wyllie Ltd).
Our Weather – 1 strip, in colour. For use with juniors (Educational Productions Ltd).
Grant's Colour Slides – Cloud Formations, with notes (House of Grant Ltd).

Classroom Work
Classroom Work on the Daily Weather Forecast – Article by A. P. Jones in 'Geography' 185 (1954).

Useful Addresses

Firms supplying school weather study apparatus:
C. F. Casella & Co. Ltd, Regent House, Fitzroy Square, London W.1 (e.g. Leaflet 908 Make-It-Yourself Kit – Stevenson Screen).
Educational Supply Association, Pinnacles, Harlow, Essex.
Griffin and George Ltd, Ealing Road, Alperton, Wembley, Middlesex.
World Meteorological Organisation, United Nations, Geneva.
U.S. Weather Bureau, Publicity Information Office, Chief, U.S. Weather Bureau, Washington, 25 D.C.

Notes on the Photographs

Frontispiece – Lightning.

Facing p. 32 – The whirling spiral formation of a hurricane clearly seen on the radarscope in one of the stations that form a network across the Gulf of Mexico and up the Atlantic coast to Canada. Storms can be kept in constant view and warnings issued immediately danger approaches. Hurricanes can be 400 miles or more in diameter.

Facing p. 33 – Launching a radio-sonde from the aft deck of O.W.S. 'Weather Reporter' with the sectional view of the radio-sonde inset. (*a*) Hygrometer unit contains a strip of single-ply unvarnished goldbeater's skin which lengthens with greater humidity. (*b*) Barometer unit with evacuated steel aneroid capsule. (*c*) Thermometer unit with a bi-metallic strip curling with temperature increase. (*d*) The windmill which rotates and drives the switch (beneath platform (*f*)) connecting each unit in turn. Transmitter (*g*) and battery (*e*) in light waterproof casing (*h*). The conical cups of the windmill (*l*) are made of bakelised paper and attached to wire arms. The aerial is a tinned copper wire sleeve forming part of the suspension of the radio-sonde in flight.

An increasing use is being made of rocket-sondes to explore and make meteorological measurements of the stratosphere at heights of 80,000 to 300,000 feet.

Facing p. 48 – An anvil or thundercloud. Note the anvil shape and the fibrous appearance of the highest edges of this cloud. A heavy shower is falling from the cloud base immediately to the right of the church steeple.

Facing p. 49 – (*above*) Hoar-frost on a window.

(*below*) Rime on the stays of the B.B.C. Television mast at Holme Moss, Yorkshire. These unusually large deposits of ice crystals were made as the supercooled droplets of a fog were blown against the stays and immediately froze.

Facing p. 64 – (*above*) Little Wymondley, Herts. Low-lying fog.

(*below*) Medium height clouds photographed over Southern Florida as an aircraft of the Hurricane Hunter Squadron flew south to investigate conditions within the 'eye' of 'Donna' in 1960. Note that many clouds are sprouting towers indicating instability of the air. These are altocumulus castellanus clouds which are usually a warning that thundery conditions are approaching.

Facing p. 65 – (*above*) Fair weather cumulus. Well scattered clouds with no great depth. The edges of the clouds are jagged and broken as evaporation takes place. The flat bases of the clouds marking condensation level are most clearly seen at the bottom left of the picture.

(*below*) Towering cumulus. The darkness of the flat bases is an indication of the vertical development of this cloud. The vigour of the boiling action within the cloud can be seen as fresh towers break out into the clear air.

Facing p. 80 – (*above*) Cirrus—mares' tails. As the ice crystals fall, the wind pulls out the trail into a curve.

(*middle*) Cirrocumulus easily recognised by the smallness and delicacy of the cloud elements. Contrast with altocumulus and stratocumulus.

(*below*) A thick layer of cirrostratus with patches of altocumulus below. Typical of the approach of a warm front.

Facing p. 81 – The altocumulus (*above*) and the stratocumulus (*middle*) differ in little but height. Both examples show the cloud elements in regular parallel lines.

(*below*) Stationary wave clouds over mountains. Wave clouds are formed where air in the crests of the waves is forced above its condensation level. The smooth arched top indicates a layer of drier, stable air above. Lenticular clouds are wave clouds which form at a height above mountains. They have a similar, smooth, gently curving appearance.

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